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UNIVERSITY OF NOTTINGHAM

REPORT OF THE SCHOOL OF AGRICULTURE

1960

COMMONWEALTH
19 MAY 1961

UNIVERSITY OF NOTTINGHAM SCHOOL OF AGRICULTURE

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SUTTON BONINGTON
LOUGHBOROUGH
LEICESTERSHIRE
1961

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INTRODUCTION

THE UNIVERSITY OF NOTTINGHAM SCHOOL OF AGRICULTURE

THE School of Agriculture in its present form came into being in 1947 with the transfer to the University College of Nottingham of the buildings and land at Sutton Bonington held by the former Midland Agricultural College. This College had its origin in the Department of Agriculture (founded in 1893) of the University College of Nottingham and in the Midland Dairy Institute (founded in 1895). These were combined in 1900 to form the independent Midland Agricultural and Dairy Institute, whose title was changed in 1906 to that of the Midland Agricultural College. For the first 30 years of its existence the principal function of the College remained the provision of certificate and diploma courses in Agriculture, Dairying and Poultry Husbandry. Collaboration between the Midland Agricultural College and the University College of Nottingham led in 1943 to the establishment of a Faculty of Agriculture and Horticulture and this was followed four years later by the transfer of the College to the University, which received its Charter in 1948.

The School of Agriculture, consisting of the four University Departments of Agriculture, Agricultural Sciences, Horticulture and Agricultural Economics, is situated at Sutton Bonington, 10 miles south of the City of Nottingham, and lies between 100 and 250 feet above sea level in gently undulating country adjacent to the valley of the River Soar. The estate extends to about 600 acres, of which 300 are arable. Two farms are operated, one for demonstration and one for experimental purposes; the remainder of the land being occupied by the Department of Horticulture Demonstration Unit, ornamental and sports grounds and buildings. The buildings comprise: a central block in which are located lecture rooms, a library, common rooms, laboratories for the Agricultural Microbiology section and administrative offices; halls of residence and a refectory; a dairy which is one of the largest in the country used for teaching purposes; two large houses—" The Elms," converted for the use of the Agricultural Zoology section, and " St. Michael's," occupied by the Department of Agricultural Economics; and a new Agricultural Sciences building.

This last building, completed in 1959, accommodates the Agricultural Botany and Agricultural Chemistry sections of the Department of Agricultural Sciences and the Animal Physiology and Crop Husbandry sections of the Department of Agriculture. Facilities are provided for postgraduate and honours students in the above sections and for labora-

tory teaching in all subjects, except Microbiology, of the B.Sc. degree course. The building is equipped with service facilities for research, including cold rooms, constant temperature rooms, plant growth rooms, a small-animal house, a radio-isotope laboratory, preparation rooms, a hydrology laboratory, spectrographic and X-ray analysis laboratories, a photographic studio and a workshop. A Field Demonstration Unit comprising, *inter alia*, a grass garden, nutrition plots and lysimeters is being developed adjacent to the laboratories, and nearby are located experimental glasshouses, a number of which are insect-proof for entomological work. The School maintains an " agro-met " meteorological station and also keeps records of incoming solar radiation.

The Department of Agriculture consists of three sections—Crop Husbandry, Animal Husbandry and Animal Physiology, each with differing requirements for research and teaching. An Experimental Farm of some 200 acres provides facilities for research. These include a slaughterhouse and cold room, rooms for metabolism and digestibility studies with cattle, sheep, pigs and poultry, a room for work with radioactive isotopes and a field laboratory. Accommodation, modified to permit individual or group feeding depending on the nature of the investigation, is available for pigs, laying hens and broiler chickens, and for a dairy herd mainly of identical twins. Some 55 breeding sows are maintained, some 7,000 head of poultry, 40 dairy cows with followers, and a breeding ewe flock. In addition to the land required for research in crop and grassland husbandry, facilities are provided on the Experimental Farm for the regional trials of the National Institute of Agricultural Botany and for an extensive series of potato variety demonstration plots for the Ministry of Agriculture, Fisheries and Food. Some 300 acres based on Manor Farm, Kingston, are farmed separately to demonstrate farm management and crop and animal production, the major enterprises being a herd of 55 Friesian dairy cattle and their followers, a Masham ewe flock for lamb production and arable cropping. A Demonstration Hall is available for teaching Farm Mechanisation and there is a fully equipped engineering workshop for the maintenance of machinery.

In the Department of Horticulture there are facilities for teaching and for research. The Demonstration Unit includes apple and pear orchards, soft fruit and vegetable plots, facilities for protected cultivation, and about an acre of heated and unheated glass; there is also a collection of hardy and tender plants of horticultural and botanical interest. Facilities for research on various aspects of the effects of weather on the growth and yield of plants include the largest installation of evapotranspiration gauges in the United Kingdom, used for detailed studies of soil/plant/water relations, and several series of plots in which plants can be

subjected to different definable and reproducible water-regimes and measurements made of the daily rate at which water is used. Ten growth rooms, some of unusually large size, are used for growing temperate or tropical plants under controlled environmental conditions of light and temperature.

The Department of Agricultural Economics is a part of the Provincial Agricultural Economics Service for England and Wales and is responsible to the Ministry of Agriculture, Fisheries and Food for the supply of economic data about agriculture in the East Midlands. It is also responsible for advisory and extension work in farm management throughout the East Midlands Province.

The objectives of the School are twofold: to enlarge the stock of knowledge relating to Agriculture in its widest sense, and to disseminate it by means of undergraduate and postgraduate courses. The University of Nottingham maintains at the School courses of instruction for the degree of B.Sc. and candidates admitted to such courses may qualify for honours degrees in Agriculture, Agricultural Botany, Agricultural Chemistry, Agricultural Microbiology, Agricultural Zoology or Horticulture, or for pass degrees in Agriculture, Dairying or Horticulture. A course is also given leading to a Diploma in Dairying. Enrolment for the current year included 145 students for first degree courses, 28 students for the diploma course and, excluding Demonstrators and Research Assistants, there are 30 postgraduate students.

Apart from the Department of Agricultural Economics, extension work in agriculture is not a function of the School, although some is effected through visits of Young Farmers' Clubs, parties of farmers and other visitors to the experimental and demonstration fields and to the laboratories, and by lectures given by members of the staff to farmers' and growers' organisations and other bodies. During the period under review members of staff have continued to co-operate with the British Broadcasting Corporation in providing programme material for Sound and Television services.

The scientific work of the School centres around the study of the principles of crop and animal husbandry, and of the problems which may be associated with them. Expressed in more precise terms the aim is to conduct researches on soil, plant and animal problems relating to agriculture and horticulture and on the insect pests which affect production. Certain aspects of the work in progress, which has reached a stage suitable for review, are described in a later part of this report.

This research work is mainly financed from general University funds, but in recent years investigations have been aided by grants from other organisations to whom grateful acknowledgement is made.

During 1960 the Department of Horticulture continued to receive support from the Agricultural Research Council to the extent of £2,759 for the development of specific research work on the water relations of plants and the use of chemical regulators. £2,000 was donated by Whiffens and Sons and Fisons for the continuation of the study of plant responses to weather.

Generous support towards the prosecution of experimental work has been received by the Department of Agriculture in the form of grants, gifts and assistance from British Drug Houses, Boots, Fisons, J. Sainsbury and T. Wall & Sons. The grant from an anonymous donor to develop experimental facilities for work with poultry and pigs has continued and in 1960 amounted to some £2,200. Support from the Pig Industry Development Authority for studies on pig nutrition, the British Egg Marketing Board for poultry nutrition and the Agricultural Research Council for potato investigation has continued. Numerous manufacturers have loaned equipment and machinery for demonstration and teaching and several farmers in the East Midlands have kindly provided facilities for experimental work with livestock. Grateful thanks are expressed to the companies and individuals concerned.

The Department of Agricultural Sciences has received £1,572 from the Agricultural Research Council for research work on poultry nutrition, and the Council has made a further contribution of £500 for the continuation of an investigation on sprout development of potatoes. Borax Consolidated have made a further grant of £500 for studies on the role of boron on root growth and Genatosan have continued to support, by a grant of £900, work on the amino-acid requirements of farm animals. The Fellowship donated by the African Pyrethrum Board for insecticidal studies has been not only continued but increased, and work on the biochemistry of the legumes has been supported by the Nuffield Foundation with a further instalment of the three-year grant of £4,450 made in 1958. An annual grant of £300 for a period of three years has been received from the Pig Industry Development Authority to support work on pig nutrition. Gifts and assistance from Fisons, Pfizer, Bourbon Products, Spillers, National Chemical Products, Bush, Beach and Segner Bayley, and the Midland Counties Dairies are also gratefully acknowledged.

THE UNIVERSITY OF NOTTINGHAM

Chancellor:
His Grace the Duke of Portland, K.G., LL.D.

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Registrar:
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Secretary to the School of Agriculture:
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THE UNIVERSITY OF NOTTINGHAM
SCHOOL OF AGRICULTURE

STAFF

DEPARTMENT OF AGRICULTURAL SCIENCES

Professor of Agricultural Chemistry and Head of Department:	E. G. Hallsworth, B.Sc., Ph.D. (Leeds), A.R.I.C.
Agricultural Chemistry:	
Senior Lecturer:	E. R. Ling, M.Sc. (London), Ph.D. (Nottingham), A.R.C.S., F.R.I.C.
Lecturers:	
Soil Chemistry	D. V. Crawford, M.A., B.Sc. (Oxford), Ph.D. (Nottingham)
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Demonstrator:	S. B. Wilson, B.Sc. (Nottingham)
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Agricultural Botany:	
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[1] Financed by Messrs. Genatosan.

[2] Financed by the Pig Industry Development Authority.

Plant Pathology	T. H. Nicolson, B.Sc. (Agric.) (Aberdeen), Ph.D. (Nottingham)
Genetics	W. J. Whittington, B.Sc. (Wales), Ph.D. (Nottingham)
Demonstrator:	B. G. Lewis, B.Sc. (Bristol)
Research Assistants:	[3] Elizabeth M. Ingersent, B.A. (Oxford)
	[4] C. R. Slack, B.Sc. (Nottingham)

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Reader:	M. Woodbine, M.Sc., Ph.D. (Manchester), F.R.I.C.
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African Pyrethrum Research Fellow:	W. N. Yule, B.Sc. (Glasgow)
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[3] Financed by the Agricultural Research Council.

[4] Financed by Borax Consolidated Ltd.

[5] Resigned December, 1960.

DEPARTMENT OF AGRICULTURE

Professor of Agriculture and Head of Department:	J. D. Ivins, B.Sc. (Reading), M.Sc. (Agric.), Ph.D. (Nottingham)
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Animal Husbandry	[6] F. R. Green, B.A., Dip. Agric. (Cambridge), Ph.D. (Nottingham)
	C. G. Payne, B.Sc. (Nottingham), Ph.D. (London)
Crop Husbandry	P. M. Bremner, B.Sc. (Edinburgh), M.S. (Cornell), Dip. Agric. (Cambridge).
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Veterinary Hygiene	J. C. Buxton, B.Sc., Ph.D. (Nottingham), M.R.C.V.S.
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Senior	[7] A. A. Wright, M.A. (Cambridge), Ph.D. (London)
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Fison Research Fellow:	R. D. Harkess, B.Sc. (Edinburgh), M.S. (Cornell).

[6] Resigned September, 1960.

[7] Fellowship expired September, 1960.

British Egg Marketing Board Junior Research Fellow:	Joy Stevens, B.Sc. (Manchester)
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	R. L. Hall, B.Sc. (Nottingham).
Research Assistants:	[8] R. W. Radley, B.Sc. (Nottingham).
	[9] D. W. Robinson, B.Sc. (Nottingham).
National Institute of Agricultural Botany Regional Potato Certification Officer:	T. Webster, B.Sc. (Agric.) (Glasgow), M.Sc. (Nottingham), Dip. Agric. Science (Wales), N.D.A.
National Institute of Agricultural Botany Regional Trials Officer:	J. C. Llewelyn, B.Sc. (Wales), S.D.A. (Hons.).

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Professor of Horticulture and Head of Department:	J. P. Hudson, M.B.E., G.M., B.Sc. (Hort.), M.Sc. (London), Ph.D. (Nottingham), N.D.H.
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	W. Heydecker, B.Sc. (Hort.) (Reading), M.Sc., Ph.D. (Nottingham), N.D.H. (Hons.)
	Winifred M. Dullforce, M.Sc. (Nottingham), N.D.H.
Temporary Assistant Lecturer:	W. R. Buckley, M.Sc. (London)
Research Assistants:	[10] J. G. Davison, B.Sc. (Nottingham).
	[11] D. V. Clay, B.Sc. (London).

[8] Financed by the Agricultural Research Council.

[9] Financed by the Pig Industry Development Authority.

[10] Resigned October, 1960.

[11] Financed by Messrs. Whiffen and Sons Ltd.

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Agricultural Economists:	R. O. Wood, M.Sc. (London)
	K. A. Ingersent, B.Sc. (Aberdeen), M.Sc. (Minnesota)
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Assistant Agricultural Economists:	H. G. Evans, B.Sc. (Wales)
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	Margaret M. Sandilands, B.A. (London)
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	Margaret Loadman, B.Sc. (Nottingham)

ADMINISTRATION

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Senior Tutor:	J. T. Morgan, M.Sc. (Wales), Ph.D. (Nottingham), A.R.I.C.
Librarian:	Nancy W. Rhodes, B.A. (London), A.L.A.
Administrative Assistant:	Muriel I. Wood
Surveyor:	C. N. Thompson, F.E.C.W., A.I.C.W.
Chief Technician:	F. C. Treeby

[12] Resigned December, 1960.

FULL-TIME POST GRADUATE STUDENTS*

	Subject	Degree
G. D. Anagnostopoulos, B.Sc. (Athens)	*Agricultural Microbiology*	M.Sc.
R. L. Burt, B.Sc. (Reading)	*Agricultural Botany*	Ph D.
D. R. Cullimore, B.Sc. (Nottingham)	*Agricultural Microbiology*	M.Sc.
B. N. K. Davis, B.Sc. (Aberdeen)	*Agricultural Zoology*	Ph.D.
K. G. Drake, B.Sc. (London)	*Crop Husbandry*	M.Sc.
D. W. R. Headford, B.Sc. (Nottingham)	*Agricultural Botany*	Ph.D.
J. M. Hopkinson, B.Sc. (Nottingham)	*Agricultural Botany*	Ph.D.
H. Jackson, B.Sc. (Nottingham)	*Agricultural Microbiology*	M.Sc.
P. C. Jain, B.Sc. (Agric.) (Delhi), M.Sc. (Ag.) (Agra)	*Horticulture*	M.Sc.
M. Jalil, M.Sc. (Ag.) (Agra)	*Agricultural Zoology*	M.Sc.
A. I. Kheiralla, B.Sc. (Nottingham)	*Agricultural Botany*	M.Sc.
J. B. Krause, B.S. (Agriculture), M.S. (Animal Science) (Illinois)	*Animal Physiology*	Ph.D.
J. E. M. Mordue, B.Sc. (Bristol)	*Agricultural Botany*	Ph.D.
W. E. Peat, B.Sc. (Nottingham)	*Agricultural Botany*	Ph.D.
S. Pickworth, B.Sc. (Reading)	*Animal Physiology*	Ph.D.
M. M. Saad, B.Sc. (Agric.), M.Sc. (Cairo)	*Agricultural Economics*	Ph.D.
J. A. T. Saul, B.Sc. (London)	*Agricultural Chemistry*	Ph.D.
A. G. Schaffer, M.Sc. (London)	*Agricultural Chemistry*	Ph.D.
J. W. Slater, B.Sc. (Nottingham)	*Agricultural Botany*	Ph.D.
M. A. Taha, B.Sc. (Agric.) (London), Dip. Agric. (Khartoum)	*Crop Husbandry*	Ph.D.
P. D. Waister, B.Sc. (Edinburgh)	*Horticulture*	Ph.D.
N. White, B.Sc. (Durham)	*Animal Physiology*	M.Sc.
T. G. Wood, B.Sc. (Durham)	*Agricultural Zoology*	Ph.D.
M. G. Yates, B.Sc. (Wales)	*Agricultural Chemistry*	Ph.D

* Excluding Research Assistants and Demonstrators.

PART-TIME POST GRADUATE STUDENTS

	Subject	Degree
D. Gunary, B.Sc. (Nottingham)	*Agricultural Chemistry*	Ph.D.
D. G. A. Guttridge, M.Sc. (Nottingham)	*Animal Husbandry*	Ph.D.
K. N. Harris, B.Sc. (Edinburgh), M.Sc. (Nottingham)	*Agricultural Microbiology*	Ph.D.
I. V. Herbert, B.Sc. (Nottingham), M.S. (Iowa)	*Agricultural Zoology*	Ph.D.
A. Loughton, B.Sc. (Nottingham)	*Horticulture*	M.Sc.
A. J. Smith, B.Sc. (Nottingham)	*Animal Husbandry*	M.Sc.

THE WORK OF THE SCHOOL OF AGRICULTURE

The problems under investigation can be classified in the following categories :

(a) Soil topics, including investigations into the nature and distribution of soil types, the processes responsible for their formation, and their relationships with physical factors;

(b) The nature of plant growth, such as internal correlations and genetic influences, and the influence of external factors, such as light, temperature, water, mineral nutrients, cultural practices, and competition;

(c) Animal growth and production, particularly with reference to grassland, the effect of nutrition, and the level and effect of hormones;

(d) Microbiological influences on plant or animal health or on the utilization of agricultural products;

(e) Chemical aspects of the utilization of agricultural products;

(f) Problems associated with insects and other invertebrates;

(g) Farm management and returns in relation to the national economy.

Brief reports of investigations in each of these fields are given below and fuller accounts of certain selected topics follow.

Soil Studies

The study of the processes of podsolization has been continued and is reported more fully in an article in this Report. The main aspect receiving attention at present is the relative contribution to iron deposition made by the fungi *Penicillium frequentans, Mucor ramannianus* and *Trichoderma viride*. These fungi have frequently been isolated from the B-horizons of podsols in this and other countries.

Work on some Derbyshire soils showed remarkable similarities between profiles on Millstone Grit shales and on the Upper Carboniferous Limestone formations; the dominant clay minerals in both groups were illites, with some evidence of kaolinites in the Millstone Grit soils. The survey of the soils of the University Farm has progressed and analyses have been carried out on representative profiles, and a collection of soil monoliths for demonstration purposes has been started. Plots to illustrate the effects of the major plant nutrients on legumes, cereals and root crops have been established.

A diamond saw, built in the workshops, has proved very satisfactory for cutting thin sections of soils, and experience is being gained in the preparation and interpretation of microscope slides. Used in conjunction with radioactive phosphorus the technique promises to be of value in studying the movement of this element in the soil.

Progress has been made in the assembly of equipment for the study of the physical properties of soils. A wind tunnel has been completed, in which the transport of particles in air can be investigated. A flume for the study of particle movement by water has been designed and has led to the development of a weir for the measurement of flow in open channels; unlike conventional weirs in general use it is accurate over very wide ranges of discharge.

An investigation has begun on soil temperatures in the field under bare and mulched surfaces. Records are maintained of relevant meteorological and soil conditions. The characteristics of the propagation of temperature fluctuations in the soil are to be related to thermal conductivity and other thermal properties of the soil. This work will constitute the first stage of a more general study of the effect of surface cover upon heat flux and soil temperature.

Plant Growth

Investigations in the Agricultural Chemistry section on the copper nutrition of subterranean clover plants grown in sand culture have been continued. The enzyme polyphenol oxidase was found to be more active in plants supplied with copper at the rate of 0.64 ppm. than in plants grown in the same basic medium but with no added copper. In plants grown in both media the enzyme was more active in the tops than in the roots. The copper-deficient plants had a higher content of orthodihydroxyphenols than the ' high ' copper plants because of the lower activity of the oxidase. A chromatographic technique has been developed to investigate further the nature of the polyphenols occurring in copper-deficient and high-copper plants. Copper-deficient plants had a higher manganese content than high-copper plants. In plants grown under constant conditions of daylength and temperature, the manganese content of the low-copper plants appeared to increase with increase in light intensity. This aspect and the effect of copper nutrition on the size and complexity of the root nodules formed are being further investigated.

In studies of the metabolism of copper-deficient plants it has been found that the alcohol-soluble amino acids and carboxylic acids increase and simple sugars decrease with copper deficiency. More specific changes

in the level of certain amino acids and carboxylic acids have been noted at varying copper levels. Compounds labelled with ^{14}C are being used to explore these effects.

An investigation has begun on the effect of copper on haem synthesis in the nodules of subterranean clover and the relationship between haem and nitrogen fixation. A copper level of 0.0064 ppm. depresses the haem content of nodules compared with those growing in a solution with ten times the copper concentration.

The effects of cobalt on the growth of nodulated subterranean clover, previously reported, have been verified. Cobalt also increases the haem concentration in the nodule but there is a complex interrelationship between copper and iron. Radioactive cobalt is now being used owing to the insensitivity of standard methods of chemical analyses and because of other difficulties encountered with stable cobalt in culture solutions. When ^{60}Co is supplied via a single leaf to nodulated subterranean clover growing in culture solutions purified for cobalt, it has been found that the nodules accumulate the isotope in preference to any other part of the plant. Work is now in progress to determine the identity of the compounds in the nodule which contain cobalt.

Detailed studies of the effects of iron deficiency on the metabolism of the yellow lupin and of the role of aluminium in the nutrition of certain calcicole and calcifuge legumes have been continued. The latter involves the estimation of pectin content and cation exchange capacity in the root, the influence of seedling reserves and embryo size upon initial growth rates and resistance to toxicity, an account of which is given later in the report, and a detailed analysis of the effect of aluminium on metabolism.

Studies of the role of boron in plant growth have continued in the Agricultural Botany section with investigations on the incorporation of uniformly labelled ^{14}C into the soluble components and cell-wall polysaccharides of the root tips of bean in various degrees of deficiency. In deficient tips there appears to be an accumulation of soluble sugars and a decrease in pectin synthesis. Further studies of the influence of boron on cell extension have been made.

Investigations on leaf growth have continued with an attempt to determine, at different stages of growth, the capacities of leaves as sinks and as sources of carbohydrates and mineral nutrients. The increased activity of the apical meristem and primordial leaves is a response to a stimulus perceived by the expanded leaves and not directly by the terminal bud. Foliar applications of mineral nutrients to expanding leaves produced little response. The results of a number of experiments in which leaves were removed and shaded at different stages of growth are being collated.

The studies of leaf expansion and internal growth correlations have been extended to include a genetical approach. Several experiments on the tomato include diallel or variance analyses of characters such as leaf expansion, rates of growth, and fruit weight, together with studies on germination and radicle extension. The examination of the genetic control of the ruptured epidermis in lucerne supports the hypothesis of control by a single gene of variable penetrance and this study is being continued. Experiments with the Xasta mutant in populations of *Drosophila melanogaster* showed an excellent example of the maintenance of polymorphism by means of chromosome inversions. An attempt is being made to discover if selection can influence the frequency of disjunction for the translocation present in this stock. A further population study is being made of the spread of linked loci using initial populations with all combinations of the genes and their alleles.

The potato has continued to receive attention. A study was made of the sprout growth of the varieties Arran Pilot and King Edward in continuous illumination at constant temperatures between 4°C and 30°C. Temperatures above 18°C killed the sprouts after several months and temperatures below 15°C resulted in retarded sprout growth, although more sprouts grew per tuber than at the higher temperatures. With increased length of time in storage there was an increase in the number of sprouts produced; further, it was confirmed that the time from planting to emergence decreases with increase in length of sprout up to a critical length of about 1.5 cm. and that any greater length at planting does not have any further effect upon the time taken to emerge.

It was stated in the Report for 1959 that potatoes planted at a high temperature and then transferred to a lower temperature after sprout emergence resulted in earlier tuber initiation associated with an early decline in leaf area and maturity. This response was confirmed using the variety Arran Pilot. It was shown that foliar applications of urea increased the leaf area of growing potato plants and delayed leaf senescence; this in turn may lead to increased tuber yields, particularly in plants which had been raised initially at high temperatures. Regrowth after an early spring frost has also been studied by the method of growth analysis. Frost-killing early in the season had no adverse effects on the final yield of tubers although the rates of bulking for about three weeks after the frost were considerably reduced. Detailed investigations on temperature relations within the growing crop were carried out throughout the growing season. Laboratory work has been concerned chiefly with the analysis of carbohydrate and nitrogen fractions within the growing plant. It is hoped that these will give some insight into the movement

of nutrients within the potato plant and possibly some indication of the mechanisms involved in tuber initiation.

The Department of Agriculture is carrying out extensive investigations on the agronomy of the potato crop. Earlier work was concerned with seed treatment; varieties; depth, time and method of planting; water relationships; seed-size; and spacing. Explanations of the yield differences brought about by some of these husbandry factors are now being sought by growth analysis. Seed-size, spacing and time of planting have been examined in detail and the work is being extended to include the effects of fertilizer treatments.

There is also considerable interest in the relationship between development before ear-emergence and yields in winter wheat; a preliminary account of this work appears in this Report. Studies of winter wheat include the effect of seed-rate on yield components, lodging as a factor limiting the response to nitrogenous fertilizer, and the influence of some husbandry techniques on the incidence and effect of " Eyespot disease " (*Cercosporella herpotrichoides*) under continuous wheat cropping.

Work has commenced on the effect of techniques of grassland management on the development and growth of herbage plants particularly in relation to the influence of autumn defoliation and the effects of temperature and nitrogen supply on the development and growth of grasses in spring.

Studies of competition between perennial rye grass and meadow fescue have continued in the Agricultural Botany section. In the winter of 1959 a considerably greater number of meadow fescue than rye grass plants died indicating a shift towards a sward in which the ryegrass predominates.

In the Department of Horticulture work continues on the effects of different water-regimes on the growth and yield of tomato and lettuce plants grown under glass. A series of eighty evapotranspiration gauges, of a pattern developed in the Department, has been used. Measurements of transpiration rates over periods of one or more days have shown interesting correlations with evaporimeter readings, suggesting that evaporimeters might be useful in the control of irrigation under glass despite the generally unsatisfactory performance of these instruments when used in the open. Work has started on the evapotranspiration rates of plants grown in the open, using a series of gauges similar to those built in the glasshouses. During the summer of 1960 a crop of grass has been used to calibrate these gauges but it is also planned to work with a range of horticultural crops.

Studies of a tropical drug plant of economic importance are being continued in a series of growth rooms, where the controlled environmental conditions under which the plants will grow satisfactorily have now been established. Investigations are being made to ascertain the most rapid and reliable methods of propagating this species and also the effects of different water-regimes on growth.

Preliminary experiments have been made on the after-effects of certain pre-sowing treatments of vegetable seeds. When germination is arrested at a certain stage, by gradually drying seeds that have previously been wetted, marked effects may be observed on plants raised from such seeds when they are exposed to drought conditions later in their life. Studies have continued in growth rooms of the factors influencing the germination of vegetable seeds and the early growth of seedlings under various conditions of soil, wind, temperature and moisture.

The effects of gibberellic acid, in conjunction with different combinations of light and temperature, on the growth of lettuce and raspberry have suggested that changes from one phase of development to the next can be accelerated and, conversely, that it is possible to keep plants in a particular phase of growth by subjecting them to the right combination of treatments.

Preliminary work has been done on the anatomical structure of the basal part of the leaf of Streptocarpus var. 'Constant Nymph.' This should give a clearer understanding of the behaviour of isolated leaves used in propagational work. When grown with a nutrient solution isolated leaves of Streptocarpus have been shown to produce progeny large enough to remove and establish as independent plants in a shorter time than when grown with water.

Studies have been made of the yield of forced rhubarb from plants lifted after receiving a known temperature regime, with a view to establishing a method for determining when dormancy of the buds has been broken sufficiently for the plants to be lifted from the field for forcing. The performance of three different varieties has been compared, and results indicate that temperatures below about 49°F have a cumulative effect on breaking of dormancy; but that there is no further increase in yield, and there may even be a slight decrease if buds are subjected to more than a certain amount of accumulated cold treatment.

Work continues on the effects of environmental factors on the growth and development of winter glasshouse lettuce varieties. The correct balance between light and temperature conditions necessary for hearting have been established by growing plants under a range of conditions in

growth rooms. This work should lead to a better understanding of the phenomenon of hearting. Growth analysis has proved to be a useful tool in evaluating the performance of different varieties.

Animal Growth and Production

The influence of stocking rates and the characters of different livestock on animal production from grassland have been investigated in the Department of Agriculture for some years. It has been confirmed that the digestibility of herbage, unlike milk yields or live-weight gains, is not greatly influenced by the type of animal, breed, stage of lactation, etc., but is mainly determined by characteristics of the herbage. The digestibility of herbage organic matter and its constituents is being determined in relation to species and varieties of herbage plants, stage of cutting, and season of growth, and to differing levels of herbage intake by sheep and dairy cattle. Work is also in progress on a study of the relationship between maximum attainable levels of milk production from herbage and the digestibility of the herbage.

Attention is continuing to be given to the methods available for characterizing the fibrous and carbohydrate constituents of animal foods. A method has been developed giving improved separation and estimation of the carbohydrate components in plant materials and is being used in association with the feeding of dairy cows. Where a lowered milk fat content is encountered the individual fatty acids of the milk fat are being determined by gas-liquid chromatography. The long-term experiment, concerned with the effect of various levels of " roughage " during rearing on the subsequent ability of the dairy cow to utilize roughage for milk production, is continuing.

The Animal Husbandry and Agricultural Chemistry sections are collaborating in a research programme concerned with the nutrition of pigs and poultry. The two basic themes underlying each individual topic are (i) it is essential to define and regulate all the variables and (ii) it is possible to use knowledge of pathways of metabolism to advance concepts of applied nutrition. Thus, in all projects, management conditions are defined, a complete analysis is made of all rations, the circumstances of husbandry are defined and the quality of the end-product is assessed.

The performance of " Wiltshire " bacon pigs is being examined in relation to variations in the dietary energy level and energy-protein ratios, and a wide range of diets are being tested at both the " starting " and " finishing " stages of growth. The effect of a variety of hormone treatments on the carcass composition of both " Wiltshire " and " Heavy " pigs has been investigated and information collected regarding the management of pigs for the manufacturing trade. Further accommoda-

tion has been planned to improve conditions for the individual control of pigs under a range of feeding regimes. Detailed studies of the role of fats in pig nutrition have commenced, including an evaluation of the digestibility of fats, a determination of energy retention within the body when rations are supplemented with fats and an assessment of the fate of individual fatty acids within the alimentary tract.

The work in poultry nutrition is continuing with more detailed studies of the dietary requirements of the broiler chicken. The optimum levels of dietary energy and protein at various stages of growth have been defined and a detailed examination commenced of the value of various fats as supplements to rations supplying all other known requirements. The part played by arginine in chick nutrition is receiving continued attention. The requirement of the bird for this amino acid is being determined in relation to other constituents in the diet, particular attention being given to the possibility of amino acid imbalance and to the related roles of glycine, methionine and citrulline. The arginine that enters the body can follow three metabolic pathways : protein synthesis, creatine formation and the Krebs urea cycle. The distribution of the enzyme systems catalysing these reactions in the chick and the kinetic properties of kidney arginase are being examined. The establishment of the identity of the pigment concerned in the pigmentation of both eggs and chicken flesh and the determination of the dietary factors that modify the degree of pigmentation are matters under investigation.

Work on the influence of growth stimulants on growth rate and carcass quality in beef cattle and sheep is reaching the final stages of preparation for publication. Comparisons have been made of the use of natural and synthetic hormones in both sheep and cattle. No further work is contemplated on the use of hydroxyzine for fattening animals. In a laboratory study ^{14}C-oestrone has been administered to male hoggets to determine the rate of excretion of its metabolites.

Experiments on the induction of extra crops of lambs from lactating ewes are continuing. Results show that the failure of fertilization previously encountered can be prevented by suitable hormone treatment but the pregnancy rate is still not satisfactory. New forms of progesterone are being tested to try to eliminate the frequent injections previously necessary. New work is in progress on the influence of a low plane of nutrition on reproduction.

Studies of the influence of ovarian hormones on the uterine environment of different species are being expanded to attempt to trace the exact effect of oestrogens and progesterone on the composition of uterine secretions and on the ability of grandulocytes to combat experimental infections.

Microbiological Problems

Studies in the Agricultural Botany section are chiefly concerned with potato diseases. Investigations on common scab are being extended to include studies of the general ecology of micro-organisms on potato tuber surfaces using periderm material; direct microscopic and cultural techniques are being used. Visual observations show that the pathogen *Rhizoctonia solani* Kühl is the dominant fungus present. The pathogenic aspects of *R. solani* on the potato are being studied in both the storage phase, when sprouts are damaged, and in the field where stem cankering occurs; the importance of inoculum on the tuber surfaces and the influence of environment are receiving particular attention.

The Agricultural Microbiology section has continued its studies on microbial fat with particular reference to whey utilization and the significance of *Lipomyces* spp. and *Hansenula* spp. Investigations have been initiated on the nutrition of freshwater algae, including their possible use for assessing the level of cations in the soil. Work on the Family Corynebacteriaceae has been continued; and the effects of sub-lethal heating on *Staphylococcus* and *Microbacterium* are being explored.

Chemical Problems in Food Utilization

Research in the Agricultural Chemistry section is at present directed towards an elucidation of the calcium phosphate-calcium caseinate relationships in milk.

In the Dairy section attention is being given to the development of a quick chemical method of detecting penicillin in milk; studies with the ultra-violet spectrophotometer have been promising. These investigations should also give a clearer understanding of protein-ion binding. A survey of the factors affecting the composition of milk, particularly protein, lactose and ash content, has been commenced.

Studies of Invertebrates

Investigations have continued on the biological characterization of the ' humus forms,' raw soil humus, pechrendzina moder, mull-like moder and moder, as they occur at Malham Tarn, Yorkshire. The faunal survey of these sites which is still in progress has been mainly concerned with the Collembola and Acarina. Techniques involving impregnation with polymerising resin, which produces sections of about 30μ, or with agar, which produces sections 0.25—0.5 mm. thick, have been employed

in making sections of undisturbed soil. The study on the re-colonization of the overburden from the Northamptonshire ironstone working has been completed.

The *in vitro* culture of *Trypanosoma theileri* Laveran and *T. melophagium* Flu, parasites of cattle and sheep respectively, has been studied. Particular attention has been paid to the cytochemistry of the cultural form of *T. theileri* with a view to analysing metabolic patterns and defining accumulated products. Some analyses of the environment favouring trypanosome growth have also been made and the data correlated with the findings of the cytochemical investigation.

The task of assessing the insecticidal performance of pyrethrum against pests of horticultural crops has continued and facilities have been established for the controlled and continuous breeding of certain species in large numbers, including *Acyrthosiphon pisum* Harris, *Pieris brassicae* L. and *Tetranychus urticae* Koch. Laboratory techniques and apparatus for accurate application of pyrethrum-water formulations to these insects have been developed and various formulations have been tested in bio-assay experiments. Several glasshouse and field trials have been carried out during the summer to assess the effectiveness against a number of pest species of those formulations which showed promise in the laboratory tests.

The survey of potato aphids on the Isle of Man was continued, particular reference being given to the importance of potential overwintering sites and the density of populations on potatoes in various regions.

Farm Management Studies

During the past year, routine investigations into farm incomes and into costs of different farm enterprises have been continued. An estimation of the variation in the gross product, based on farm management surveys for four years, has been completed; this has allowed the separation of " managerial " from random influences. A study of the economics of housing the dairy cow has been completed.

Earlier adoption of new farming practices was found to be mainly associated with high gross income and large farm size and with young farmers who have received a fairly high level of general education. An account of this investigation appears in this Report.

Studies of the economics of fertilizer use for beef production on grassland, of egg production and milk production are continuing and an analysis of the market structure of the poultry, vegetable and soft-fruit industries of the East Midlands has been commenced.

SEVENTH EASTER SCHOOL IN AGRICULTURAL SCIENCE

April 1960

RUMINANT DIGESTION

D. Lewis

The subject of the 7th Easter School in Agricultural Science was "Digestive Physiology and Nutrition of the Ruminant." The proceedings were divided into three main sessions: general physiology, metabolism in the rumen and nutrition of the ruminant.

Dr. A. T. Phillipson (Rowett Research Institute) opened the conference with a historical account of concepts of general physiology in relation to the rumen. He pointed out that the first thing one noticed about animals possessing this very large organ, the rumen, was their ability to chew the cud—to ruminate. Nobody has yet been able to measure how good or how necessary this is for their digestive processes. The other feature of the rumen he considered in detail was the oesophageal groove, a structure which enables milk that is swallowed to by-pass the rumen and enter at once the last compartment of the stomach. A general account of the physiology of rumination and the location of related active centres in the brain was given by Dr. F. R. Bell (University of London).

Drs. R. S. Comline and D. A. Tichen (University of Cambridge) followed with an account of the nervous control of movements of the ruminant stomach and Dr. C. C. Balch (National Institute for Research in Dairying) described the actual movement of digesta through the alimentary tract. Dr. S. Hyden (University of Uppsala) in his paper on the use of markers to follow fluid flow in the alimentary tract described his elegant method based on the use of polyethylene glycol. The secretory activity of the ruminant digestive glands was described by Mr. K. J. Hill (A.R.C. Institute of Animal Physiology) who has developed excellent techniques for the collection of bile and pancreatic juice in the ruminant. Dr. A. Dobson (Rowett Research Institute) gave an account of the absorption of metabolites from the rumen and the session on general physiology was closed by Professor R. W. Dougherty (Cornell University) with an account of his studies on the mechanism of the process of eructation.

The second main session, concerned with metabolism in the rumen, was opened by the paper of Dr. C. A. E. Briggs and Mr. L. A. Davey (National Institute for Research in Dairying) on descriptive microbiology. They explained the importance of diet on the microbial population and described their own studies on the fluctuation in numbers of lactobacilli and streptococci. Rightful emphasis was given to the work of Hungate, Bryant and their colleagues in the U.S.A., who have isolated and examined in detail most of the prominent organisms that attack cellulose and other carbohydrates. Dr. P. N. Hobson (Rowett Research Institute), who described techniques of counting rumen organisms, pointed out the difficulty of achieving a counting procedure that was significantly related to events *in vivo*. Despite all the potential problems, counts make it possible to assess the importance of a particular organism in the rumen and to demonstrate changes in number and types of organism as the diet is altered.

An account of carbohydrate metabolism in the rumen was given by Dr. G. Halliwell (Rowett Research Institute) who paid particular attention to cellulolytic processes. He emphasised that too much of the study of this process has been carried out with degraded forms of cellulose and that alleged cellulolytic organisms had seldom been tested using native cellulose fibres. Dr. D. Lewis (University of Nottingham) gave a general account of the fate of nitrogenous compounds in the rumen and Dr. G. A. Garton (Rowett Research Institute) discussed the influence of the rumen on the digestion and metabolism of lipids. He pointed out that the main effects were the hydrogenation of unsaturated fatty acids, the hydrolysis of glycerides and phospholipids and the fermentation of glycerol. Dr. E. Brouwer (University of Wageningen, Holland) discussed mineral inter-relationships in the ruminant and the session was closed by Dr. J. C. Shaw (FAO), with a description of techniques used for studying rumen metabolism with special reference to the use of radio-isotopes.

The final session was concerned with the nutrition of the ruminant. The merit of the possession of a rumen can be simply stated to be due to the ability to digest cellulose and to synthesise certain amino acids and vitamins. The three main contributors who opened this section were essentially concerned with these points: Dr. J. W. G. Porter (National Institute for Research in Dairying) gave an account of vitamin synthesis in the rumen and showed that except for vitamin B_{12} there is little evidence that adult ruminants ever suffer from a deficiency of vitamins of the B complex; Dr. M. I. Chalmers (Rowett Research Institute) discussed the importance of protein synthesis particularly in

relation to the supply of what are called 'essential' amino acids; and Dr. K. L. Blaxter (Hannah Dairy Research Institute) gave a very clear account of energy utilization in the ruminant. His outstanding work demonstrates in quantitative terms the amount of energy made available to the ruminant by the absorption of volatile fatty acids from the alimentary tract. Energy requirements of ewes in late pregnancy were discussed by Dr. R. L. Reid (C.S.I.R.O. Sheep Biology Laboratory, Australia).

A group of papers was presented on the inter-relationships of endocrinological factors and nutrition. Dr. D. B. Lindsay (A.R.C. Institute of Animal Physiology) discussed the relative importance of acetate and glucose in satisfying the energy requirements of ruminants and Dr. A. A. Wright (University of Nottingham) gave an account of possible mechanisms for the effect of oestrogens on growth. The comments on endocrinology were completed by the paper of Dr. G. E. Lamming (University of Nottingham) in which he brought together general concepts of the correlation of endocrinological factors in the regulation of growth and nutrition. The final paper given by Dr. M. J. Head (Spillers Limited) and entitled "Cellulose digestibility and the rumen" showed clearly how the ruminant, by means of microbial digestion, is able to make efficient use of the nutrients of grass.

The ruminant represents the most developed form of herbivore and because it possesses a rumen it is able to extract the maxium of nourishment from coarse fibrous foods. However, although the rumen is such a remarkable structure and accomplishes such an enthralling range of activities, its significance must be kept in perspective. It must be viewed in proper relation to other digestive organs.

The proceedings were published in December 1960 by Butterworths Scientific Publications, London, under the title "Digestive Physiology and Nutrition of the Ruminant."

THE ACCUMULATION OF IRON AND ORGANIC MATTER IN PODZOL SOILS

D. V. Crawford

The illuvial or B-horizons of podzol profiles are zones where iron, aluminium and organic matter, leached from the upper layers, accumulate. These horizons possess two features which contribute to the processes of accumulation : first, there are sesquioxides, clay and organic colloids with extensive, charged surfaces which may attract and retain substances washed down the profile, and secondly there exists a specialized flora of micro-organisms dominated apparently by a limited number of species of fungi,[1] which may cause precipitation by their metabolic activities. Investigations have been made to discover the relative importance of these two mechanisms of accumulation, but it was necessary first to study the nature of the extracts which would leach as far as the lower zones where this deposition occurs.

Incubation of fresh soil samples from different podzol horizons with water showed that iron, aluminium and silicon were the main inorganic constituents of the extracts obtained, but calcium, magnesium, sodium, potassium and phosphorus were also found, especially in the extracts from the surface horizons; organic matter was abundant and dialysis showed that 80-90% of this and of the iron and aluminium were present as a brown colloidal complex. Anaerobic incubation increased the amounts in the extracts of all constituents, particularly of iron which under these circumstances could be detected in a stable ferrous form. Also a greater proportion of the iron passed through the dialysis membrane. Two other notable features of the behaviour of iron were that during aerobic incubation its solubility decreased, and a sterilant (phenyl mercuric nitrate) suppressed the formation of ferrous iron under anaerobic conditions.

The evidence of these incubation experiments suggests that biological activity in the eluvial horizons of iron-humus podzols makes an important contribution to the mobilization of iron and aluminium. Chelating agents derived from the above-ground parts of plants have also been suggested, but to be effective they would need to survive decomposition during their passage through the layer of leaf litter.

The extracts leach through the relatively inactive A-horizons without much hindrance until ferruginous sand or the colloids of the B-horizon are reached, and there absorption of some of the iron and organic matter takes place slowly but thoroughly. The negative charge on the colloids in the extract suggested that there may be a connection between the

amount of absorption and positive charges on the absorbing soils; such charges are associated with coatings of hydrated iron or aluminium oxides. The retention of chloride and ammonium ions were measured at pH 4 and expressed as anion and cation exchange capacities, and various other properties of the absorbing soils were determined. No comprehensive pattern was found when the results of absorption by fourteen soils from ten extracts were studied, though the soils could readily be divided into two groups. The Group I soils were from B_{Fe} – and C-horizons, and absorption of iron was highly positively correlated with one or both of the exchange capacities for some of the extracts; absorption of organic matter was closely associated with anion exchange capacity but less so with cation exchange capacity.

The other group of soils (Group II) included some from B_H-horizons which were richer in humus : they all had higher cation exchange capacities than the Group I soils. In striking contrast to the Group I soils absorption of iron was negatively correlated with anion exchange capacity, though this barely reached the 5% level of significance. Better positive correlations were obtained between iron absorption and the carbon contents of the soils, or between the organic matter absorption and the carbon, clay or aluminium contents of the Group II soils.

The absence of a comprehensive pattern of absorption is perhaps not surprising in view of the heterogeneous nature of the incubated extracts, and also of the complex surface characteristics of the varied soils used for absorption. The highly significant correlations obtained in some instances give grounds for believing that if the extracts could be fractionated and characterised more precisely, a logical pattern might emerge.

A physical sorption process is indicated by the evidence of saturation —or a limit to uptake—which the Group I soils show in relation to increasing iron and organic matter contents of the extracts : this is less obvious for the Group II soils.

The absorption of organic matter and its concentration in a local zone provides the condition which Estermann and McLaren[2] suggest will favour microbiological development. To test this, extracts and soils were heat-sterilized, and some of the soils were re-inoculated with organisms from B-horizons; the extracts were leached very slowly through the soils and the leachates analysed for iron and organic matter. The results in Table 1 were obtained using a coarse sandy C-horizon soil for absorption. Where the ratio $\frac{\text{Inoculated extract}}{\text{Sterile extract}}$ has a value of less than

one there is evidence that the micro-organisms are assisting the deposition of iron or organic matter, and this clearly occurs with some of the extracts. The last example in Table 1 shows appreciable divergence between the duplicates, one of which (6(b)) gave rise to a thin pan in the absorbing soil (Fig. 1). This was exceptional, but Fig. 2 shows an effect which has been observed with various dark-coloured extracts : the zone of accumulation is more compact in the presence of organisms than in the sterile controls.

TABLE 1

	Soil and conditions of preparation of extract	Inoculated extract / Sterile extract	
		Iron	Organic matter
1	F+H horizon Aerobic, 34 days	1.48	1.04
2	,, Anaerobic, ,,	2.72	0.87
3	B_H – horizon Aerobic, ,,	0.16	0.87
4	,, Anaerobic, ,,	0.20	0.61
5	,, Aerobic, 83 days	0.25	0.80
6	,, Anaerobic, 63 days	(a) 1.21 (b) 0.75	1.06 0.83

Various factors alter the influence which micro-organisms have on the movement of iron and organic matter and some are still under investigation. The use of mixed cultures prepared from fresh soil for inoculation may ensure that all the appropriate organisms are present, but it makes control more difficult since slight differences in the packing of the absorbing soil column may cause different organisms to dominate replicates; this is suspected to be the cause of the discrepancy between extracts 6 (a) and 6 (b) (Table 1). A compact soil column associated with easily metabolized organic constituents in the extract may induce anaerobic conditions and favour iron mobilization rather than deposition. Pure cultures of *Mucor ramannianus, Penicillium frequentans,* and *Trichoderma viride* are also being employed to discover whether any of these fungi are effective; they have been selected because of the frequency with which they have been isolated from podzol B-horizons.

The visual and chemical evidence obtained from the leaching experiments, together with the previous observations that aerobic incubation reduces the solubility of iron from B-horizon soils, point clearly to a contribution which micro-organisms make to the formation of illuvial podzol horizons. The organisms involved are heterotrophic and presumably utilize part of the organic groupings which maintain the sesquioxides in mobile colloidal form. It is known that some hydroxy-acids, such as citric acid, readily peptise these colloids, and there may be a sequence of acid formation in the upper horizons followed by destruction in the

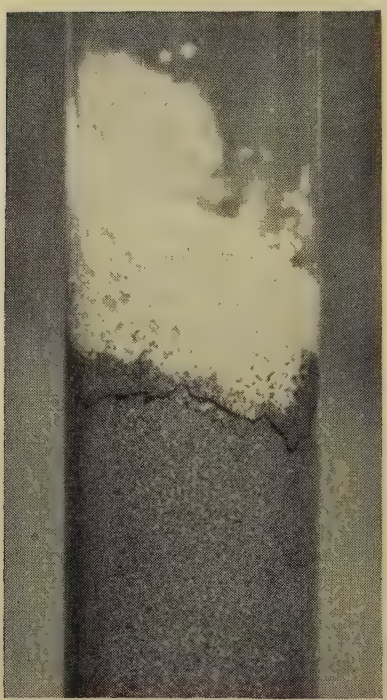

FIG. 1

Thin pan forming in absorbing soil beneath washed sand.

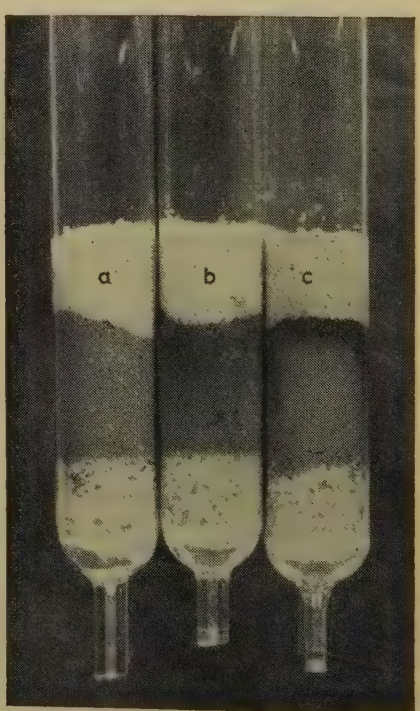

FIG. 2

Influence of organisms on thickness of artificial B-horizon. (a) Before leaching with extract. (b) Sterile leaching. (c) Leaching with organisms present, after 40 days. The absorbing soil is retained between layers of washed sand, and the compact, dark zone in (c) may be compared with the diffuse staining visible in (b).

lower horizons; such a sequence could be influenced by the relative availability of a trace element such as zinc in the different parts of the profile. Other workers have shown that lack of zinc induces some organisms to form abnormal amounts of citric acid[3]. The combination of sorption and microbiological deposition would explain the progressive accumulation of iron and organic matter within a restricted depth of the podzol profile, while differences of aeration and drainage arising from soil texture, rainfall and other environmental factors would account for some of the variations observed in the depth and morphology of B-horizons in different profiles.

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PRELIMINARY INVESTIGATIONS ON RHIZOBIUM BACTEROIDS

D. C. Jordan

Bacteria of the genus *Rhizobium* are capable of invading the root hairs of leguminous plants and of producing localized swellings (nodules) wherein atmospheric nitrogen is converted into organic forms which can be used by the plant. Within the nodules the bacteria become swollen and distorted and are known as bacteroids. In contrast to the free-living or "cultured" rhizobia these bacteroids have received relatively little attention from the physiological standpoint.

Most of the present investigations were carried out on washed bacteroids obtained by centrifugal methods from the crushed nodules on plants of subterranean clover (*Trifolium subterraneum*) grown in sand with two copper levels in the nutrient solution (0.32 and 0.0064 ppm.).

Under the light microscope it can be seen that in the initial stages of nodule development the rhizobia appear in the host cytoplasm as small uniformly basophilic rods. Gradually these cells become less intensely stained. They swell and sometimes branching occurs. This process is repeated as new cells of the root cortex are invaded by the rod-forms. Consequently, a suspension of these nodule bacteria reveals

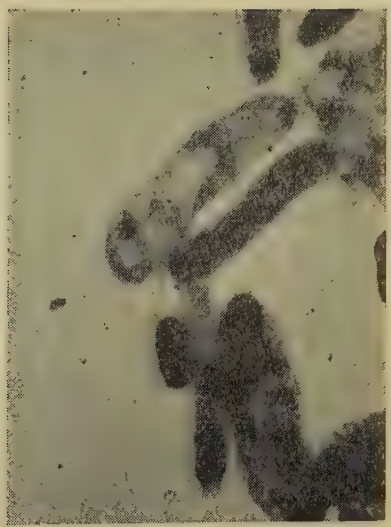

FIG. 1

Various cell types present in a washed suspension of *Rhizobium* bacteroids obtained from the nodules of *Trifolium subterraneum L.* X 14,250.

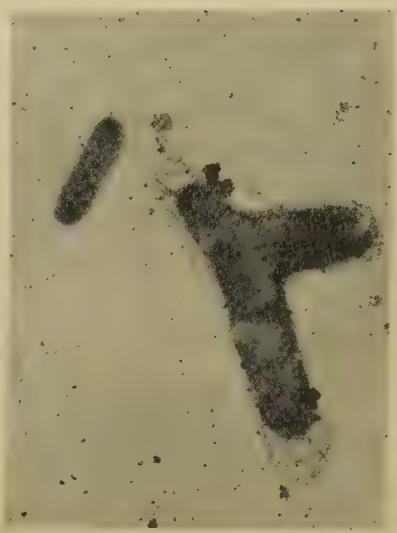

FIG. 2

A plasmolysed bacteroid, showing the collapsed cell wall. X 18,400.

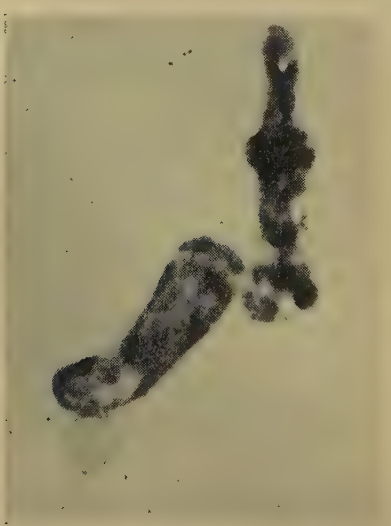

FIG. 3

Two bacteroids, one of which shows a typical "bleb" in its outer envelope. This phenomenon does not occur with laboratory-cultured rhizobia. X 15,450.

FIG. 4

The globular structure formed from certain bacteroids upon incubation in distilled water. Prepared by the phosphotungstic acid technique. X 30,000.

a variety of cell types under the electron microscope (Fig. 1). The cells range from small "electron-dense" rods, through elongated rods with a low degree of vacuolation, to the large bloated cells which are 50% or more "electron-transparent" and which can be considered as mature bacteroids. The scattered remnants of "electron-dense" material in these cells give the appearance of banding and granulation under lower magnification. There is distinct evidence of two external layers about each cell as can be clearly seen in plasmolyzed cells (Fig. 2) and in preparations stained by the phosphomolybdic acid and methyl green technique. This is of interest since Bergersen and Briggs [1] have reported that the majority of isolated soybean bacteroids are devoid of a cell wall. However, there is some evidence of a weakening in the cell wall since many cells show "blebs" (protrusions) in their outer envelopes (Fig. 3). Also when bacteroids are dialyzed against distilled water the cells swell and become only faintly stained. Many disappear entirely and round structures, suggestive of proto- or spheroplasts, are sometimes seen (Fig. 4). Bacteriophage is often present in the bacteroid suspensions and intracellular 'phage' development can be observed in infected bacteroids by the use of the phosphotungstic acid negative stain used in conjunction with electron microscopy. This technique also reveals the gummy material which adheres to isolated bacteroids despite extensive washing in various buffers.

Bacteroid suspensions at pH 7 give a positive microscopic Nadi-reaction which indicates perhaps the presence of cytochrome oxidase. The reaction is sensitive to heat and azide and is apparently localized in small granules arranged about the internal periphery of the cells. No polyphenol oxidates could be demonstrated but these cells are capable of synthesizing glutamate from alpha-ketoglutarate and various amino donors via transamination (Table 1).

TABLE 1

MICROGRAMS GLUTAMATE SYNTHESIZED IN TWO HOURS AT 30°C AND pH 7.8 PER MG. BACTEROID NITROGEN. (ENDOGENOUS VALUES OF GLUTAMATE WERE SUBTRACTED).

Amino group donor	"High-copper" bacteroids	"Low-copper" bacteroids
Aspartate	92	100
Alanine	97	83
Isoleucine	145	178
Histidine	trace	trace
Valine	132	183
NH_4Cl	0	0

In collaboration with Dr. R. Cooper of Rothamsted Experimental Station glutamine synthetase was investigated in soybean nodule fractions. Soybean seeds were planted in a soil : peat mixture and inoculated

with a heavy suspension of root nodule bacteria (strain ≠ 502 which is partially effective, strain ≠ 505 which is effective). After numerous trials a fractionation procedure was developed and several centrifugal fractions from nodules were analysed for their ability to synthesize glutamine according to the reactions :

$$\text{glutamate} + NH_3 + \text{ATP} \rightleftharpoons \text{glutamine} + \text{ADP} + \text{P}$$

The protein and nucleic acid percentages of three of these fractions (from 72-day old nodules) are given in Table 2. The reaction mixtures were modified several times in an attempt to reduce the synthesis of glutamine outside the cells and for other reasons. Results for two types of reaction are shown in Table 3.

TABLE 2

Component	Composition of Fraction (% dry weight)		
	bacteroids	S	P
Protein	77.0	32.5	38.4
Nucleic acid	14.0	11.5	9.3

S and P denote the supernatant and pellet respectively at 29000g. for 10 minutes.

TABLE 3

Reaction Mixture	Fraction	Glutamine synthesized (m_μM/mg. dry weight)	
		Endogenous	after 1 hr.*
A	S—Rhizobium 505	150	200
	P—Rhizobium 505	5	60
AB (modified to reduce endogenous synthesis of glutomine)	S—Rhizobium 505	5	70
	P—Rhizobium 502	5	80

* endogenous subtracted

Values obtained for glutamine synthesis by intact bacteroids are subject to a considerable error because, in the chromatographic analysis for this compound, the cells interfere with the proper migration of glutamine. However, these cells only appear to synthesize about 7% of the glutamine formed by the fraction contained in the supernatant (S) obtained after centrifugation.

The assistance of the electron microscopy units of the University of Cambridge and Boots Pure Drug Co. is gratefully acknowledged.

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EFFECTS OF HIGH AND LOW MOISTURE ON SEED GERMINATION AND EARLY GROWTH OF VEGETABLES

Walter Heydecker

The United Nations Food and Agriculture Organization has initiated a world seed campaign in order to stress the importance of using "good seed". This concept implies a number of properties such as a high genetic potential including the yield capacity of the resulting plants and the quality of produce, and particularly the ability to germinate and produce plants under a variety of conditions which are often far from favourable. The conditions during germination may be critical, since the transition from seed to independent seedling is perhaps the most delicate stage in the life of a plant. Investigations are in progress on the requirements for satisfactory seedling establishment.

Experiments were designed to find marginal conditions which would unbalance the air and water supply to the germinating seed, and to investigate possible after-effects of stringent conditions on subsequent growth. The seeds were sown in boxes filled with field soil and placed in a growth room at 60°F. All seeds were dressed with a fungicidal dust based on captan.

Lettuce and Peas

In order to study the importance of a continuous supply of sufficient water during germination, temporary drought conditions were simulated. Twenty seeds each of lettuce "May King" and peas "Kelvedon Wonder" were sown per box on the soil surface which was kept moist throughout by capillary water supply. The boxes were

either (c) kept covered throughout with tightly fitted sheets of glass

or (−/c) kept uncovered for 4 days before being covered

or (c/−/c) covered for 4 days, then uncovered for 4 days, then covered again

The results are summarised in Table 1.

TABLE 1

PER CENT ESTABLISHMENT OF SEEDS

	Sown on surface of soil		
	(c) covered throughout	(−/c) uncovered 4 days, then covered	(c/−/c) covered 4 days, then uncovered 4 days, then covered
Lettuce	67.5	77.5	82.5
Peas	85.0	77.5	42.5

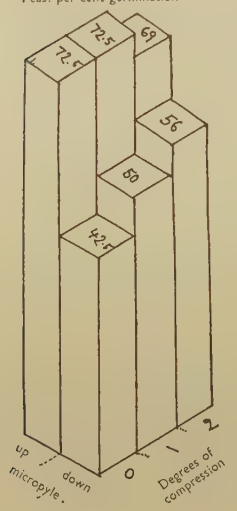

Fig. 1
Peas: per cent germination

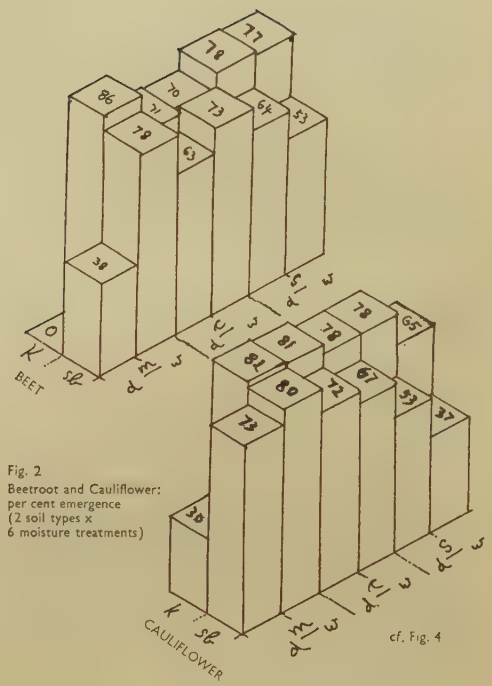

Fig. 2
Beetroot and Cauliflower:
per cent emergence
(2 soil types x
6 moisture treatments)

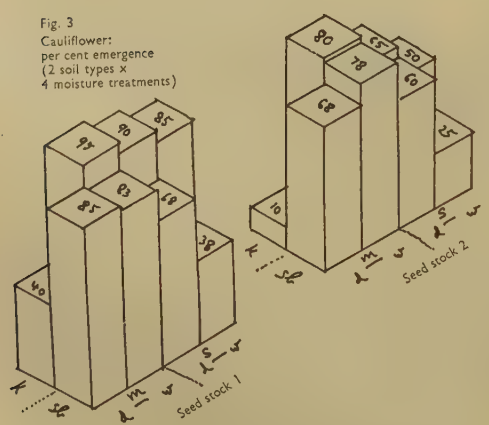

Fig. 3
Cauliflower:
per cent emergence
(2 soil types x
4 moisture treatments)

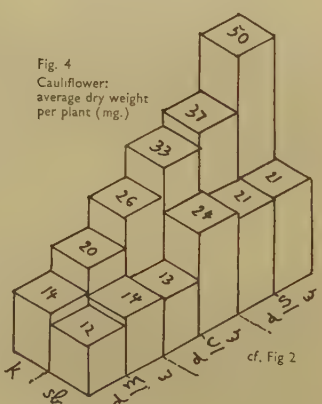

Fig. 4
Cauliflower:
average dry weight
per plant (mg.)

FIGURES 2—4:

soils	k = well structured clay loam sb = poorly structured sandy loam
watering	m = original moderately moist state (see text) c = watered by capillary rise of water s = watered by saturation
drying	w = kept at original degree of wetness d = dried by exposure to wind

Lettuces germinated well irrespective of treatment. Peas imbibed water rapidly in all treatments, but in treatment (– /c) no germination occurred by the fourth day, whilst in (c) and (c/ – /c) radicles began to split the testas and were in the process of emerging. By the eighth day, after which all boxes remained covered, both (– /c) and (c/ – /c) had been exposed to a stream of drying air for four days but at different stages. In (– /c) where the onset of germination had been delayed, seeds now began to germinate and grow normally; seeds in (c/ – /c), exposed to a drying atmosphere after their radicles had begun to emerge, proved to be permanently checked; a few resumed growth hesitantly, but most did not grow and became covered by mycelium of various fungal species, despite the fungicidal seed dressing. This result indicates that, from a certain stage onwards, an uninterrupted moisture supply is essential for the germination of peas, and that this moisture must be supplied at such a rate as to prevent net moisture loss to which large seeds like peas are more prone than small seeds like lettuce; also a larger quantity of water is required for the germination of a pea than for a lettuce seed.

On the other hand, growers appreciate that peas may fail to germinate in wet soil. In order to test whether this is true even in the presence of a fungicidal dust and, if so, whether it is due solely to a lack of aeration or, in part at least, to mechanical obstruction, peas were sown in a poorly structured sandy loam with their bases a quarter of an inch below the soil surface, i.e. approximately half-buried. In each box one row of 20 seeds was sown with the micropyle facing upwards and one row with the micropyle downwards. Before sowing the soil had been compressed to varying degrees,—firmly (2), moderately (1) or not at all (0). Results are presented in Figure 1. Germination was much poorer where the micropyle had been buried, indicating that even a very thin layer of wet soil can be an effective barrier to aeration and that this itself can be responsible for germination failure of peas; far from providing a supply of air, the looser soil proved a more efficient "water seal", and lowered the germination per centage more than when the micropyle was buried in firm soil.

These two experiments demonstrate that the small step from insufficient to sufficient, and from sufficient to excessive, moisture may have profound effects on the germination of peas; even "good seed" will fail unless care is taken in seedbed preparation and sowing to guard against both extremes.

Cauliflower and Beetroot

Three seedsmen's stocks of cauliflower (var. "All the Year Round") and beetroot (var. "Detroit") were sown at a depth of $\frac{3}{4}$ inch in two soils, a well-structured clay loam (k) and a poorly structured sandy loam (sb), and then subjected to one of three moisture treatments:

(s) — immersion of the boxes to their rim in water which entered through the basal drainage slots;

(c) — capillary rise of moisture;

(m) — no watering, i.e., soil kept at its initial, standardized, moderate moisture content.

Then (w) — half of the boxes were kept as far as possible at their original moisture level by a polythene cover,

whilst (d) — the others were exposed to the drying air of the room for four days and then covered.

Results for cauliflower and beetroot are presented in Figure 2. It is seen that drought is a relatively more limiting factor for beetroot and excessive wet for cauliflower germination; however, for both species, to ensure satisfactory results from watering, the soil must be either naturally well structured or watered carefully.

When the individual stocks of cauliflower are compared (Fig. 3), the establishment of stock No. 1 proves more consistent than that of stock No. 2 which, though fairly satisfactory under favourable conditions, fails in more rigorous environments. Stock No. 3, not illustrated, is intermediate.

Dry weights of seedlings show that: (a) the average weight of plants of the three stocks agrees well with their relative ability to produce good stands, No. 1 being distinctly superior in "vigour". (Mean germination in soil and mean seedling dry weight: Stock No. 1: 78%, 31 mg.; No. 2: 57%, 19 mg.; No. 3: 63%, 21 mg.); (b) drought retards growth as well as depressing germination (Fig. 4); (c) moist soil, though more beneficial to germination than wet soil, is less able to sustain growth (Fig. 4). It appears that, in order to obtain first a satisfactory stand and then satisfactory growth, a modicum of moisture for germination should be followed by an ample water supply.

Carrot

Numerous reports of experiments, chiefly based on the pioneer work of P. A. Henkel and which are described in *Physiologia Plantarum* and other Soviet publications, purport to show that seed can be "drought-hardened", i.e. subjected to one or more drying cycles in the early stages of germination, so that the resulting plants become more capable of resisting the effects of soil or atmospheric drought, high soil salinity, frost or heat experienced later in life. A pilot experiment along these lines was carried out on carrot (var. "Ideal") by J. W. Slater. Carrot seeds were given three cycles of 24 hours' imbibition followed by air-drying and then sown in three-inch pots at the same time as untreated control seeds. The soil was kept at field capacity by capillary sub-irrigation. After five weeks water was withheld for one week from half the plants grown from both treated and control seeds by wrapping the pots in polythene. By the end of this period all the wrapped plants had begun to wilt. After further four weeks with ample water, there was no clear difference between any of the treatments in the weights of the tops of plants but exposure to drought had considerably reduced root growth in the plants raised from seed which had not been pre-treated (Table 2), on the other hand where the seeds had been "drought-hardened" the weight ratio of edible root to top was hardly lower, despite a week's drought, than where the water supply had been maintained throughout. This result represents no more than a strong trend and requires confirmation. But if such a conveniently practical manipulation of seeds could be shown to lead to higher yields of edible parts of this and other important crop plants grown under adverse climatic conditions, e.g. in arid regions, the result might be of considerable agricultural interest.

TABLE 2

RATIO OF WEIGHT OF EDIBLE ROOT TO FOLIAGE IN CARROT (S.E. ± 0.22)

Moisture supply to growing plants	Seed treatment	
	drought-hardened	untreated
Permanent	3.66	4.[illegible]
Removed for 1 week	3.38	3.75

The experiments reported demonstrate the complementary importance of maintaining both moisture and air supply for germination and early growth, of the species-specific tolerance to environment, of selecting a high quality stock of seed, and the fascinating prospects offered by manipulation of seeds before sowing.

THE GROWTH OF SAINFOIN SEEDLINGS

I. H. Rorison

When the effect of certain acid soils on the seedling establishment of sainfoin (*Onobrychis sativa* Lam.) was studied, it was noted that a small percentage of seedlings survived despite the death of the majority. Death of the many occurred because of aluminium toxicity and associated effects[1] but reasons for survival of the few are also of great interest and are being investigated. Seed size was an obvious factor to consider, as a range of seed weights is found even on single plants due to the different times at which seeds mature and to the consequent variation in supply of nutrients from the parent plant to the different individuals on an inflorescence.

It is agricultural practice to harvest seeds at one time when the majority are mature but of various weights. The smallest seeds, whose embryos are most likely to be incompletely differentiated, are discarded on cleaning. In the field, seed of sainfoin is normally dispersed as it matures and therefore, unless parent nutrient supply ceases too early, it is probable that nearly all seeds leaving the plant are fully differentiated. This is a point which awaits experimental investigation. Speed of growth seemed to be the key to survival but it was not known which seed component or combination of components gave survivors their initial advantage. Four possibilities were considered:

(1) *Hypocotyl size,* because it is mainly by extension of the hypocotyl following imbibition that the radicle emerges into the soil and the cotyledons are pushed above ground before they unfold and photosynthesis occurs;

(2) *State of embryo differentiation*;

(3) *Cotyledon area* which determines the extent of the photosynthetic area at unfolding; and

(4) *Nutrient reserve* which is largely stored in the cotyledons and is often expressed in terms of cotyledon weight.

It was thought that sainfoin being non-endospermic and having epigeal cotyledons would depend, under favourable conditions, largely upon hypocotyl size for speed of emergence and upon cotyledon area for subsequent growth. Under adverse conditions nutrient reserves might also play an important part.

As many workers had found seed weight a good guide to subsequent performance, individually shelled and weighed seeds were used. Seeds ranging in weight from 10 to 20 mg. were sown in soil and water cultures, each having a different nutrient concentration. Samples of each seed weight dissected after one hour's imbibition showed that the weight of hypocotyl, testa, and cotyledons increased with increasing total seed weight. The respective weights from a 12 mg. seed were 0.66, 2.23, and 8.25 mg; from a 15 mg. seed, 0.78, 2.63 and 10.69 mg; and from an 18 mg. seed, 0.87, 3.04 and 12.68 mg. Speed of radicle emergence was not influenced by any of the nutrient solutions used but it varied significantly according to original seed weight as did subsequent cotyledon emergence and unfolding. Thus it was possible to associate hypocotyl weight with the speed of emergence of seed planted at the same depth. Greater speed of emergence from the heaviest seeds meant that the dry weight of the resulting seedlings began to increase most quickly. This was only an initial temporal effect and subsequent growth *rates* were independent of original seed weight.

Because leaf and leaflet number per plant was shown to be independent of seed weight it was inferred that there was the same number of leaf initials in all the seeds used. This implied that heavier seeds merely had heavier embryos and not different degrees of morphological differentiation.

As both cotyledon area and leaf area varied with original seed weight it could be seen that for the heavier seeds there was an initial advantage of a larger photosynthetic area unfolding more rapidly following emergence above ground. Therefore their initial capital (*sensu* V. H. Blackman) was due to two major factors; (1) hypocotyl weight influencing speed of emergence and (2) the earlier unfolding of larger photosynthetic areas.

Speed of morphological differentiation and of growth was influenced by external nutrient supply. All seedlings lost dry weight until the cotyledons had unfolded, and the higher the external nutrient concentration and the heavier the seed the smaller was the loss and the quicker was the original weight regained and passed.

To follow nutrient movement within seedlings, an analysis of the various parts was carried out for phosphorus. Phosphorus was chosen because it is a mobile essential element associated with soil acidity problems and also one which under normal conditions is taken up rapidly in the early phases of growth. A typical pattern shown in Table 1

suggests that initially as the root, and later as the shoot, began to grow rapidly some phosphorus was translocated from the cotyledons. For 17 days at least in this external concentration of phosphorus (P = 3 mg./1.), the cotyledons played a part in phosphorus supply. In the full nutrient solution (P = 30 mg./1.) cotyledon phosphorus content did not fluctuate so much, while in distilled water there was a steady loss from the cotyledons throughout.

TABLE 1

TOTAL PHOSPHORUS IN SAINFOIN (μg./PLANT FRACTION)
(18-mg. SEEDLINGS GROWN IN DILUTE NUTRIENT)

Plant fraction	Time (days)						
	0	5	7	9	11	14	17
Cotyledon	30.0	27.0*	27.6	39.8	39.7	30.0	20.6
Root	3.6	1.5*	13.1	20.1	23.2	33.5	35.0
Shoot	(hypocotyl)	—	—	—	2.9	20.5	30.6

* Data obtained by extrapolation

This basic pattern of growth of sainfoin is similar in many ways to that established by Black[2] for subterranean clover. When seed is planted at the same depth radicles of the biggest seed emerge and start to absorb nutrients first, and the cotyledons from these also emerge first and, therefore, start to photosynthesise earliest. The *rates* of growth and of morphological differentiation are independent of original seed weight and are influenced only by variation in external factors such as nutrition, climate and plant competition. Final *yield* from any one environment is, however, dependent upon original seed weight to a degree which decreases with time. Some evidence for movement of phosphorus within the seedling grown in solutions of various external concentrations has been found, and further work to explore the relationship between seed size, phosphorus metabolism, and resistance to aluminium toxicity is planned.

The generosity of Smith Brothers (Basingstoke) Limited in supplying seed and details of harvesting is gratefully acknowledged.

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SOME ASPECTS OF EAR DEVELOPMENT IN WINTER WHEAT

P. M. Bremner and A. P. Ingham

Investigation into the physiological basis of yield in cereal crops has shown that much of the dry matter in the grain is a product of photosynthesis occurring after ear emergence. It seems unlikely that there is translocation to the ear after it has emerged, of more than negligible amounts of the assimilate stored in the plant in the pre-ear emergence phase. The evidence for this is based upon experiments involving shading and defoliation[1, 2, 3] and, more recently, upon work with radioactive carbon[4, 5], the last being mainly of a qualitative nature.

The organs principally concerned in the manufacture of the photosynthate involved in filling the grain are the flag leaf, the stem and the ear. Quantitative estimates of the contributions made by these organs vary: the ears, stems and leaves of wheat were found to contribute, according to variety, from 18 to 45%, 27 to 44% and 23 to 44% respectively[2], whilst a feature of the work of Watson *et al.*[3] with barley is the importance of the flag leaf and peduncle (59%). It is reasonable to suppose that the contributions from the various organs concerned might be affected by environmental as well as genetical factors. Indeed, Frey-Wyssling and Buttrose[6] suggest that this is so to such an extent as to invalidate many of the estimates obtained by shading and defoliation: they consider that a decreased contribution from one source is offset by increases from other sources, and that, in consequence, an estimate of the ear's contribution obtained by shading it is an underestimate, the deficit being partly made good by other organs. They claim the normal contribution by the barley ear to be in the region of 75%. Be this as it may, the size of the ear at emergence is of obvious importance with regard to yield in cereal crops, because the surface area of the ear determines, in part, the size of the photosynthetic system responsible for grain filling, and also because it determines the number of positions in which grain may set. Attention is, therefore, focused on the *pre-emergence* environment of the ear and its possible effects upon ear size, and indeed on the wider question of the relationship between vegetative growth before ear emergence and yield.

Vegetative development before ear emergence may affect yield by influencing the extent of tillering and the number of ears produced; in addition, it may govern the size of the ears produced. The former effect is generally appreciated, but the latter has received little attention, despite the fact that the matter is of some practical importance in connection with the grazing of cereal crops intended for grain production. Holliday[7] has shown that, except where it reduces such adverse

secondary effects of excessive vegetative growth as lodging, grazing almost invariably leads to decreased yield. The mechanism of the yield reduction is obscure, and no doubt the effect cannot be interpreted simply as one of vegetative development upon yield, since the issue is confounded with damage which might concurrently be done to apices. However, grazing before mid-April in this country probably results in little or no apical damage, since most of the apices are at or below ground level until this time; for such grazing Holliday quotes losses of 3—44%.

The relationship between vegetative growth and ear development has been investigated in two ways: first, the effect of defoliation on the initiation and early development of the ear has been studied in winter wheat (var. Cappelle) grown in soil in an unheated glass house; second, the relationship between the leaf area of individual shoots and the size of the ears they contained has been investigated in a field crop of Cappelle.

In the defoliation experiment there were three clipping treatments: unclipped (C_0); clipped at 5 weeks, or the 2—3 leaf stage (C_1); and clipped at 12 weeks or the 4—5 leaf stage (C_2). Clipping involved the removal of all laminae, leaving one inch of leaf sheath. There was no damage to the stem apices. In addition to the clipping treatments, there were three levels of nitrogen (0, 3 and 6 cwt. per acre 23% N fertiliser, N_0, N_3, and N_6 respectively) and two spacings (1 inch and $\frac{1}{2}$ inch between plants, Sp_0 and Sp_1 respectively, the distances between rows being 6 inches in both). For convenience, ear initiation and stem elongation were induced early in the season by extending the day length with artificial lighting.

The course of ear initiation was followed by weekly examination of the apices in the main shoots of single plants and that of ear development by taking fortnightly samples of four plants per plot. From these the ears of the main shoots were dissected, their length measured and spikelets counted. Tillers were ignored in these measurements.

With regard to ear initiation, the onset of the " double ridge " stage was delayed by two weeks, and spikelet and floret initiation by one week in both the clipped treatments as compared with the unclipped. Spikelet and floret initiation appeared to take place at the same times in the clipped treatments (though sampling at closer than weekly intervals might have revealed small differences) but the length of the apex when these stages were observed was markedly different. Thus the action of, but not the time of clipping appeared to affect the morphological development of the ear; both the action of, and the time of clipping had a pronounced effect upon the size of the ear when the morphological changes occurred.

TABLE 1

MEAN EAR LENGTH (mm.) AND SPIKELET NUMBER IN SAMPLE HARVESTS (CLIPPING TREATMENTS AVERAGED OVER ALL LEVELS OF N AND SPACING)

TREATMENT	HARVEST							
	1 (23 March)		2 (6 April)		3 (20 April)		4 (5 May)	
	Length	No. of spikelets	Length	No. of spikelets	Length	No. of spikelets	Length	No. of spikelets
C_0	2.12	20.9	10.76	22.7	36.6	22.5	159	22.2
C_1	1.55	18.4	8.86	21.3	27.8	21.8	134	21.6
C_2	1.21	15.6	7.03	21.2	18.3	21.6	89	21.4
S.E. mean	±0.05	±0.34	±0.35	±0.55	±2.16	±0.34	±1.48	±0.32

Subsequent development in length of ears is shown in Table 1 and it is apparent that defoliation resulted in a reduction of ear length from the earliest stages until the final sampling. Clipping just before ear initiation (C_2) was especially harmful in this respect. Ear emergence commenced within a day or two of the final sampling, and within a week the ears of all the main shoots had emerged. Clipping had only a small effect on time of ear emergence, C_0 preceding C_1 by two days, and C_2 by four days.

Projection to time of emergence of the curves for increase in length of the ear, on the basis that C_0 had reached almost maximum length at the time of the final sampling, suggests that whilst ears of C_1 may have been only slightly smaller than those of C_0 at emergence, the ears of C_2 were some 2 cm. shorter. The photosynthetic capacity at emergence of ears of the main shoots was, therefore, reduced by clipping at the time of ear initiation. It is possible that the capacity of the ear to set grain was also affected: C_1 and C_2 consistently had fewer spikelets per ear than C_0, though this effect was not significant after the first harvest.

Unfortunately, extensive bird damage prevented yield data being obtained, but there can be little doubt about what relative yields would have been; ears were smaller in the clipped treatments, and unless their number and/or grain size were increased, then yield reduction must follow. Clipping reduced the number of fertile tillers (again C_2 suffered especially) and it seems unlikely from other work that grain size would be increased by clipping.

Much less information was obtained regarding the effects of nitrogen and spacing due partly to the type of design used and partly to the amount of variation. Ears were bigger with the wider spacing except at the first sampling. Nitrogen suppressed growth in general at all

stages, this being most noticeable when the N_6 treatment was combined with the C_2 treatment. This suppressing effect of nitrogen cannot be explained on the basis of any of the data collected.

The above experiment may give some indication of the effect of vegetative growth on ear development. However, it could be argued that the consequences of defoliation do not reflect the effect of decreased surface *per se* upon ear development: defoliation has other effects—for example, it entails the removal of a sink for and later a source of minerals, and it alters the balance of photosynthetic to respiratory tissue. A more direct approach to this problem would be to seek a relationship between the leaf area of individual shoots and the size of the ears they contain. To this end samples of winter wheat (var. Cappelle) were taken at three different times before ear emergence from a field experiment involving 4 rates and 2 times of nitrogen application and 2 seeding rates. The samples consisted of 10 shoots (main stems and tillers) per treatment chosen to represent approximately the range in shoot size in each treatment. The leaf areas of the individual shoots in these samples were measured and the ears dissected and measured. There was a linear relationship ($r=0.9$) between length of ear and leaf area on each occasion. Moreover, the correlation and regression coefficients did not appear to be affected by the treatment, the implication being that treatments influenced the size of developing ears through their effect upon the leaf area of individual shoots. This tentative conclusion will be investigated further.

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THE EFFECT OF GROWTH SUBSTANCES ON TOMATOES

J. G. Davison

Growth substances have long been employed as "fruit-setting" materials in tomato growing but their more widespread use as selective herbicides for controlling weeds in agricultural crops has caused much concern amongst horticulturists. Droplets and vapour of herbicides may drift some distance and inadvertently damage unsprayed susceptible crops such as tomatoes. Although it has not been possible to assess the extent of such spray damage, substantial financial losses have been incurred by individual growers.

Severe spray damage to plants results in morphological changes which are readily recognised but slight spray drift may also cause modifications which are not always immediately apparent. Such modifications have been recorded in experimental work involving the application of growth substances to tomatoes. The most interesting work in this connection is probably that of Hitchcock and Zimmerman[1] who provide the most complete list, so far published, of morphological changes brought about by the growth substance 2,4-dichlorophenoxyacetic acid (2,4-D).

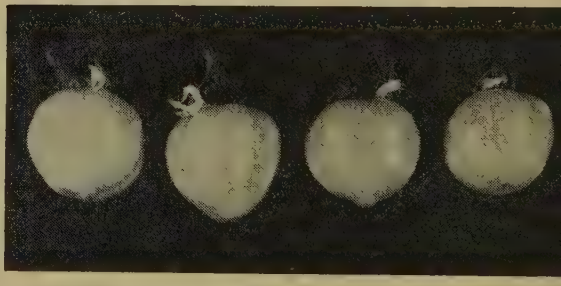
Since it was difficult to determine whether slight morphological changes noticed in a crop of tomato plants were, in fact, due to spray drift and also because it was not known whether spray damage reduced yield, experimental work on these aspects was undertaken at the request of the Agricultural Research Council during the period 1957-60. In most other work only very small plants have been used but here plants up to five feet high have been completely sprayed with growth substances (Table 1). All plants were grown under commercial conditions. It was hoped (a) to define the smallest morphological change which could be recognised as a growth-substance response; (b) to estimate the effect on yield; and, conversely, (c) to obtain information on the type and position of response which would assist in estimating the approximate date on which spray drift might have occurred in spray-damaged crops.

Both nastic and formative changes occurred on the leaf and stem; the former resulted from all but the lowest concentrations of growth substances. In affected plants there was a downward bending of leaflets and petioles and, occasionally, also bending of the stem (Plate 1a). Such responses occurred within 24 hours of treatment but usually persisted only for a few days; within a week the plant appeared normal. Formative effects depend on a change in the pattern of development and therefore take longer to become apparent. The most sensitive formative response

(a)

(b)

(c)



(d)

PLATE 1

MORPHOLOGICAL CHANGES IN TOMATO PLANTS FOLLOWING APPLICATION OF GROWTH SUBSTANCES

(a) EPINASTIC RESPONSE. Photograph taken 24 hours after spraying with MCPA.

(b)—(d) FORMATIVE RESPONSES. (b) Leaf modification after spraying with 2,4-D; (c) Stem proliferation following application of mecoprop; (d) Fruits with "beaks". (Notice also remains of petals trapped between calyx and fruit).

TABLE 1

GROWTH SUBSTANCES USED AND THE APPROXIMATE AMOUNT OF EACH RETAINED (μg. per plant) BY INDIVIDUAL TOMATO PLANTS

Growth Substance*	Type of Crop	Stage of Development	Level of treatment			
			Control	Low	Medium	High
MCPA	Glasshouse	2nd truss flowering	0	15	60	240
		6th ,, ,,	0	20	80	320
Mecoprop		2nd ,, ,,	0	120	—	400
2,4-D		,, ,, ,,	0	60	—	200
2,4,5-T		,, ,, ,,	0	60	—	200
2,3,6-TBA+MCPA		,, ,, ,,	0	60	—	200
MCPA	Outdoor	1 day after planting	0	1	5	27
		14 days after planting	0	2	12	58
Mecoprop		,, ,, ,, ,,	0	12	—	58
2,4-D		,, ,, ,, ,,	0	12	—	58
2,4,5-T		,, ,, ,, ,,	0	12	—	58
2,3,6-TBA+MCPA		,, ,, ,, ,,	0	12	—	58

* MCPA denotes 4-chloro-2-methyl-phenoxyacetic acid
Mecoprop denotes *a*—(4-chloro-2-methyl-phenoxy) propionic acid
2,4-D denotes 2,4-dichlorophenoxyacetic acid
2,4,5-T denotes 2,4,5-trichlorophenoxyacetic acid
2,3,6-TBA denotes 2,3,6-trichlorobenzoic acid

was leaf modification : in some treatments, e.g. MCPA, there was a reduction in mesophyll development with a considerable reduction in leaf area and modification of the vascular pattern. Mecoprop and 2,4,5-T did not evoke this response. Dissection of the growing points showed that only those leaves initiated before MCPA was applied subsequently became modified. Though modified, all leaves retained their basic imparipinnate form with seven leaflets. More severe leaf modification followed treatment with 2,4-D (Plate 1b) and the mixture of 2,3,6-TBA and MCPA: even leaves not initiated at the time of treatment were influenced. In some instances simple leaves, and forms intermediate between simple and normal, were produced. However, the plants always continued to grow and eventually produced normal leaves above the modified leaves. Each growth substance used also produced proliferations of stem tissue, which appeared as raised areas of lightly coloured tissue (Plate 1c). On occasions the outer layer ruptured and adventitious roots emerged but generally development was arrested before this stage was reached. On many stems the outer layer of tissue died, thus providing a site for the entry of *Botrytis spp.*

The fruits are produced in groups known as trusses. Above the first truss, which occurs in the region of the eighth to the tenth node, successive trusses usually occur at three-node intervals. The number of a truss may

thus be used to denote a position on the plant. Under normal circumstances a prerequisite of fruit development is the opening of the flower followed by pollination and fertilisation. Therefore yield may be affected by the number of flowers which open and/or which develop into fruit and by the size attained by individual fruits. Low concentrations of growth substances may induce fruit development but most workers interested in " fruit-setting " substances have sprayed open flowers which subsequently produce parthenocarpic fruits; these grow more rapidly and become larger than those from untreated flowers. Hemphill[2] sprayed flower buds and flowers at various stages before anthesis and found that pollen and ovary development could be disturbed to such an extent that fruit development was prevented. In the present work both flowers and fruits were present at all stages of development at the time of application. In a glasshouse crop, in 1959, the highest rate of application of MCPA reduced the number of flowers which opened during the following two to six weeks. Low levels of MCPA accelerated flower opening, resulting in a significant increase in the number of flowers which were open by the second week after treatment. As with flowering, no changes in the total number of fruits developing occurred until the second week after treatment; by this time all concentrations of MCPA had increased the number of fruits larger than 1 cm. in diameter. However, this appeared to be the result of an increased rate of growth. Between the third and sixth weeks after treatment significantly fewer fruits developed on plants which had received MCPA at the highest level, a result to be expected following the reduction in the number of flowers that opened on these plants.

All of the growth substances used reduced the yield on those trusses which at the time of treatment had either no, or only a few, flowers open. With MCPA yield was significantly reduced on three trusses, only the lowest of which had a few flowers open at the time of spraying. Reduction in yield in the two youngest trusses can be accounted for by fewer fruits being produced from the smaller number of flowers opening; here there was a significant increase in individual fruit size.

Growth substances also changed the shape of the fruit. All types used induced " beaking," i.e. the presence of a protruberance at the style end of the fruit (Plate 1d). This abnormality was confined to those trusses which at the time of treatment were flowering or about to start flowering. A further abnormality was the production of elongated fruit which occurred only on those plants treated with either 2,4-D or the mixture of 2,3,6-TBA and MCPA, and on flowers not open when the growth substance was applied.

The morphological abnormalities described have been observed on two varieties of tomato, Moneymaker and Potentate, grown in a glasshouse, and on Moneymaker grown in the open. Such formative effects persist and therefore may be used for the diagnosis of spray damage. For this purpose, the most useful response would seem to be that of leaf modification which was confined to leaves which were expanding at the time of treatment. The time taken for modification to become apparent is important. Modification of the largest leaves affected was not observed until 10 days after treatment, by which time they were almost fully developed, although stem proliferation, which occurred below the level of leaf modification, was noticeable after 7 days. Epinasty was the most rapid response, occurring within 24 hours, but this was a less sensitive response than leaf modification.

The association between morphological change and effect on yield depends on the growth substance concerned. Low levels of MCPA may result in an increased yield together with slight leaf modification whereas consistent decreases in yield are accompanied by more definite modifications. On the other hand mecoprop and 2,4,5-T may reduce yields without producing any recognisable modification of the vegetative organs. Reduced total yields may be accounted for by the reduced yields of two or three trusses. At the time of application of a growth substance these trusses are in an early stage of development, having flowers or only very small fruit present. In the event of a tomato crop being affected by spray drift the full extent of the damage could probably not be assessed until after a sufficient time had elapsed for such trusses to produce ripe fruit.

ACKNOWLEDGMENT

This work has been supported by financial grants from the Agricultural Research Council, whose support is gratefully acknowledged.

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CROP VARIETY TESTING

J. C. Llewelyn

N.I.A.B. Regional Trials Officer

The National Institute of Agricultural Botany continued its main series of trials at the School of Agriculture in 1960, with a similar programme to that of the previous year.

A sugar beet trial was introduced to study the early vigour of varieties especially in relation to weed suppression. The time of sowing trial was replaced by a small-scale trial of 15 varieties. Three varieties were added to the main sugar beet trial. In addition to a thousand head kale trial, a marrow stem kale trial was re-introduced, both trials having three dates of cutting. Sixteen varieties of kale were also grown for observation purposes.

The spring cereal trials were reduced to four replicates with only two nitrogen levels. This enabled the number of varieties in trials to be increased. Plots were again laid down to assist in the study of loose smut, mildew and yellow rust.

The out-centre trials were continued on the farm of W. Smith at Wilson. These consisted of a winter oats, a winter barley, a silage maize and a brussels sprout trial. The winter barley trial was discarded owing to damage by sparrows prior to harvest.

The results of the main 1960 trials are summarised below. These by themselves have a limited application and should be used only as a very tentative guide to varietal performance.

Cereals

Autumn sowing conditions were excellent and the clemency of the weather which followed enabled the winter cereals to establish and over-winter well.

Spring cereals established well and remained vigorous throughout the season. Mildew was moderate, yellow rust absent, except in the susceptible wheat variety—Michigan Amber (Yellow Rust Collection). Take-all disease greatly reduced the yields of the winter wheat varieties, S.E.116/57 and Champlein. There was a considerable amount of loose smut in certain varieties of spring barley.

High winds, heavy rain (1.8 ins.) and thunderstorms on the 23rd June and in the early morning of the 24th, caused severe lodging in the out-centre trials, and considerable lodging in the spring barley trial. Prolonged rain in July caused further lodging.

In the tables the main control variety is listed first with the yield in cwt. per acre. The yields of other varieties, with the secondary control listed first, are expressed as a percentage of the main control, and are in heavy type where they differ from it significantly (5% level). All yields are at 15% moisture content, and are the means of yields obtained at three levels of nitrogen (winter cereals) and at two levels of nitrogen (spring cereals).

WINTER WHEAT TRIAL

c/a=cwt. per acre

	Hybrid 46	Cappelle Desprez	Hesbignon	Maître Pierre	S.80	14431	Champlein (13179)	Falco (Civ. 237)	S.E. 116/57	TB. 31/23	Vilmorin G.
c/a	31.9	105	98	98	101	94	**84**	103	**63**	**110**	**111**

No lodging. Slight leaning in Cappelle Desprez, Maître Pierre and TB. 31/23. Hesbignon was more susceptible to mildew.

WINTER OATS TRIAL

	S.147	S.172	Powys	5370/2/2/41	E.2296	E.2297	32/78/4
c/a	40.8	96	100	**112**	**115**	**113**	**112**

Severe lodging in medium and high N plots.
S.172 and 32/78/4 showed most resistance to lodging.

SPRING WHEAT TRIAL

	Atle	Koga II	E.L.S.	Probat	Ring (5323)	Fylby	Grano (Strubes 6339/48)
c/a	28.5	**112**	105	**120**	**110**	107	**116**

Slight lodging in all varieties except Fylby, rather worse in Atle.

SPRING BARLEY TRIAL

	Proctor	Maythorpe	HB 196/10/5	HB 281/6/5/9	Delta	Elsa	Hillmarsh	Pallas	Sv. 50/102	W. 5492
c/a	37.2	96	98	100	**93**	**91**	**91**	97	97	98

HB 281/6/5/9 was resistant to mildew.
Maythorpe was particularly weak-strawed.
W.5492 had considerable loose smut; Elsa, HB 281/6/5/9 and HB 196/10/5 had a moderate infection of loose smut.

SPRING OATS TRIAL

Sun II	Milford	Max	Phoenix	Civ. 1688	Flamings Krone	Marino	Vollbringer
c/a 38.0	89	97	81	100	99	92	101

Civ. 1688, Flamings Krone and Marino showed good resistance to lodging.

Beans

A trial to compare the relative yields of spring and winter beans was continued for the third successive year. Establishment and subsequent growth was excellent. Chocolate spot which appeared early on the winter beans became aggressive in late July. A moderate infestation of black aphis appeared too late to justify the inclusion of a systematic spraying treatment.

The mean yields were as follows:—

Gartons S.Q. (winter) ... 33.7 c/a.

Albyn Tic (spring) ... ... 25.0 c/a.

Potatoes

Majestic was the control in all trials. Varieties are given in order of their actual yields, with the highest yielding first.

All trials emerged well and growth was generally vigorous until blight appeared at the beginning of August. Development was fairly rapid and most varieties were completely blighted by the end of the month. The varieties, 120/18, Reaal and 148/5 were not affected.

The wet autumn made harvesting extremely arduous. There was a high incidence of diseased tubers.

MAINCROP POTATO TRIAL

	Majestic	Pentland Crown	Ulster Beacon	Seedling 120/18	Ulster Tarn	Ulster Glen	Ulster Torch	Ulster Grove	Ulster Ranger
Total tons/acre	20.9	19.9	19.2	17.8	16.5	15.9	14.7	12.7	11.7
Over 2"	14.9	16.7	16.2	11.7	11.0	11.6	8.0	6.2	8.4

FOREIGN VARIETY TRIAL: Seed ex. N. Ireland

	Majestic	Ontario	Cherokee	Yampa	Katahdin	Cayuga	Seneca
Total (tons/acre)	21.4	23.4	19.4	17.5	16.2	14.8	13.5
Over 2″	14.8	20.5	17.6	14.9	14.5	9.3	10.8

FOREIGN VARIETY TRIAL: Seed ex. Cumberland

	Majestic	Sebago	Etoile du Leon	Kennebec	Canso	Pungo	Russet Burbank	Saco
Total (tons/acre)	16.4	19.1	17.1	15.5	15.3	11.3	9.7	7.5
Over 2″	10.5	16.8	9.0	13.4	12.1	5.9	4.8	5.4

YELLOW FLESH VARIETY TRIAL

	Majestic	Panther	Solanum	Reaal	Orion	Acker-segen	Regent	E.57 (Clarke)
Total (tons/acre)	21.8	21.8	21.7	21.6	21.5	21.5	21.3	21.2
Over 2″	15.3	14.5	16.4	15.2	18.5	12.5	13.5	18.5

	Record	Monica	F.37 (Clarke)	Aronia	Fruhperle	E.62 (Clarke)	Bintje	Rhondine
Total (tons/acre)	21.1	19.7	17.7	17.3	17.0	14.7	14.7	11.9
Over 2″	13.0	10.3	14.2	9.7	9.6	9.3	7.0	6.1

Sugar Beet

Sharpe's Klein E was the control in each trial, and the data of other varieties are related to it as a percentage.

MAIN SUGAR BEET TRIAL

	Sharpe's Klein E	Battle's Polyploid A	Desprez TM.	D.S.G.	Garton's 632	Goldsmith's Dobrovice A	Logie Polycross	Polygrave	Zwaanpoly
Population/acre	32,400 (100)	97	99	102	**104**	103	100	100	101
Bolters %	0.04	0.04	0.00	0.04	0.12	0.52	0.00	0.12	0.00
Yield of Tops t/a	14.3 (100)	97	105	**113**	**109**	103	**111**	**111**	104
Yield of Washed Roots t/a	23.5 (100)	94	98	97	96	90	86	95	100
Sugar %	14.4	14.9	14.6	14.8	15.3	15.4	15.1	15.2	15.0
Yield of Sugar t/a	3.4 (100)	97	100	99	102	96	**90**	101	104

SMALL SCALE SUGAR BEET TRIAL

	Sharpe's Klein E	Battle's Polyploid D	Bush Monogerm Triploid	Desprez EA	Desprez ER	Desprez GO	Dieckmans E
Population/acre	32,600 (100)	87	86	100	96	91	95
Bolters %	0.00	0.51	0.21	0.35	0.09	0.49	0.47
Yield of Tops t/a	14.9 (100)	82	100	94	93	100	106
Yield of washed roots t/a	23.4 (100)	94	86	80	87	92	91
Sugar %	14.6	14.6	15.4	15.8	15.6	15.4	14.7
Yield of Sugar t/a	3.4 (100)	94	91	87	93	97	91

	Garton's LT. 1237	Maribo N	Multa-verna	Polykuhn	Webb's 392	A.J.3	C.L.R.	M.L.R.
Population/acre	103	99	99	91	100	95	93	93
Bolters %	0.09	0.09	0.00	0.00	0.00	1.40	5.44	11.83
Yield of tops t/a	102	100	94	93	90	109	91	87
Yield of washed roots t/a	92	84	88	92	96	69	69	67
Sugar %	14.8	15.3	15.0	15.8	15.6	16.5	15.8	16.1
Yield of Sugar t/a	93	88	91	99	102	78	75	73

Silage Maize

Yields as a percentage of mean yield of the whole trial.

Variety	Plant height (inches)	Green * Yield	Dry † Yield
Caldera 402	84	92	89
Foliant	91	95	99
Kelvedon Kingscrost 40	85	111	114
Kelvedon Kingscrost KC3	94	105	108
M.B.G. 5-8	102	120	105
Maisking 5	92	106	106
Pioneer 395	82	91	95
Warwick 277	73	88	95
Wisconsin 335A	87	90	89

Mean yield:

* 100=31.4 tons per acre of green material.

† 100=4.82 tons per acre of dry material.

CORYNEBACTERIA AND LOSSES OF FARM STOCK

A. Seaman

The Corynebacteria are a group of bacteria which resemble the tuberculosis group and the threadlike actinonycetes in some respects and the true bacteria in others. As with most border-line groups there is no general agreement on which organisms should be included, and apart from the major pathogen, *C. diphtheriae,* they have received little publicity. Yet many of them are capable of causing outbreaks of disease, either in plants or animals. The animal diseases are usually sporadic and often chronic in nature, and so do not draw a great deal of attention, but it is just this type of disease pattern that is likely to increase as the more dramatic illnesses are brought under control. It has been the policy of the Microbiology Section to direct a short but intensive investigation on different members of this group.

C. pyogenes[1] has been reported as a cause of disease in most types of farm animals. Except in the cow, the illness is usually in the form of abscesses or arthritis. In the calf, the bacterium also produces abscesses and, as it is clearly related to *C. renale* (see later), it is interesting that these may be in the kidney. In the adult cow *C. pyogenes* will cause infections of the reproductive system. This infection is usually severe enough to prevent conception or, if the cow is already in calf, will cause abortion. Estimates of the incidence of abortion due to *C. pyogenes* vary but figures up to 12% have been quoted.[1] Lowered fertility may also result from infection of the bull. Added to the loss of livestock is the loss of milk yield from cows in which the udder is infected with *C. pyogenes.* This form of mastitis is usually called "summer mastitis" although it may actually occur at any time of the year. *C. pyogenes* is often found to be growing in association with other bacteria which are responsible for the foul odour which the gland develops. It has been suggested that this mixed flora accounts for the sporadic success which antibiotic treatments have been shown to have.

Preliminary experiments in this laboratory indicated that there might be two physiological strains of *C. pyogenes,* one very active metabolically and one less so. It was considered that infections due to the active strains might be those resistant to treatment, but further work[2] showed that the apparent greater metabolic activity was due to habituation to laboratory conditions. Tests of antibiotics made in litmus milk (to give the laboratory conditions as near as possible to those in the natural infection) showed that most antibiotics were ineffective. Two interesting points which were demonstrated were (i) that the same strains of *C. pyogenes* gave a very variable response to Bacitracin in different tests

and (ii) that Chloromycetin, Erythromycin and Dihydrostreptomycin delayed the growth of *C. pyogenes* considerably and only Chloromycetin continuously exerted any appreciable effect. A combination of these two effects is sufficient to explain the uncertain result of treatment of " summer mastitis."

C. renale[3] is more specific than *C. pyogenes* in the part of the body which it infects. It causes inflammation of the ureter and necrosis of the kidney. The highest incidence is in the cow, but it has been suggested that the disease is more widespread in pigs than is appreciated. Damage to the urinary system during a difficult birth is one of the predisposing factors. The infection is not normally noticed until it is well advanced; the urine then is foetid, contains blood, and smells strongly of ammonia. The bacteria are characterised by the production of large amounts of an enzyme, urease, which converts the urea in the urine to ammonia. The irritant effect of the ammonia is the first step in the establishment of the disease. There is considerable difference in the amount of urease produced by different strains of *C. renale* but the work at this laboratory did not link this with differences in pathogenicity. Diagnosis of the disease can only be made after the kidneys have been considerably damaged, and often the disease is recognised post-mortem. Penicillin is still the most effective antibiotic of those tested in this laboratory and has been used in the field with apparent success. Complete recovery is rare, relapses being frequent even after antibiotic treatment.

Listeria monocytogenes[4] forms a separate genus in the family of Corynebacteria. It is a pathogen which causes disease in man and a wide variety of other animals. The typical disease in cows is a form of encephalitis but abortion and mastitis have also been recorded. In calves the common form of infection is in the liver, associated with wasting and general weakness. As with other corynebacterial infections it has been suggested that *Listeria* may play a greater role in calf mortality than is appreciated. In sheep the main form of infection is encephalitis when infected animals tend to wander in repeated circles. This " circling sickness " is world-wide and appears to be on the increase. In lambs the infection may appear either as encephalitis or as septicaemia. In pigs the infection leads to paralysis and death. Treatment of any farm animal is rarely successful. The conflicting reports of success with some antibiotics only underline their general ineffectiveness. Tests in this laboratory suggest that combinations of antibiotics may be more successful than the use of single antibiotics in the field.

Erysipelothrix rhusiopathiae.[5] This causes " swine erysipelas," which is the most important disease of pigs in four European countries and is world-wide in distribution. The infection may be acute, with fever

and red patches on the skin, or chronic with arthritic changes in the joints. Either form may cause damage to the heart. Swine erysipelas can be controlled by vaccination or immunisation, but it has been suggested that the only way to eradicate it is by the use of vaccination instead of immunisation.[6] Erysipelas is also important in turkey flocks, where it can be cured by penicillin. Infection of sheep and lambs, where the disease is usually of the arthritic type, seems to be increasing.

This brief survey has shown that the diseases caused by bacteria of the Corynebacteria family are often chronic in farm stock and are considered to be increasing in incidence. As the more acute infections are brought under control the farmer is bound to become more familiar with these four diseases and those involving the other ten bacteria of this family which cause animal disease. Horticulturalists may well find the same situation with the eleven or so related bacteria which cause plant diseases.

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DIETARY VARIATIONS IN PROTEIN AND ENERGY AND THE PERFORMANCE OF GROWING/FATTENING PIGS

J. T. Morgan and D. W. Robinson

In common with other farm livestock the salient criteria of productive efficiency in the pig are growth rate, economy of food utilization and carcass quality. However, the pig industry is unique in that objective standards of carcass assessment are applied commercially, and in order to meet the stringent requirements of the Wiltshire bacon trade in particular, feeding systems which prejudice the attainment of maximum growth rates have frequently to be implemented. Conformation and body composition are primarily under the influence of ancestry and

nutrition. The breed or type is of fundamental importance and variation in performance arising from this source constitutes a very considerable obstacle to the application of isolated research findings to the pig population at large. The data given in Table 1 illustrate this aspect very clearly.

TABLE 1

CHANGES IN THE CHEMICAL COMPOSITION OF PIGS WITH AGE (1)

(Figures in percentages)

		Water	Protein	Fat	Ash
At birth*		81.5	12.4	1.9	4.2
At 30 Kg.*		58.5	13.0	25.4	3.1
At 100 Kg.	Bacon breed	50.4	13.4	33.1	3.1
	Fat breed	44.2	11.4	41.9	2.5

* Breed differences were not evident.

The classic experiments of McMeekan(2) showed that dietary changes, both quantitative and qualitative, may also greatly influence carcass quality; the phenomenon of phasic development of the body was demonstrated by growing pigs according to pre-determined growth curves. It subsequently became practice to consider the post-weaning period in two phases, viz. from weaning to approximately 16 weeks (approx. 100 lb. liveweight), and from this point to slaughter. Diets suitable for growing pigs are, however, fed up to weights ranging between 90 and 140 lb., and in view of the economy in feeding which results from the earliest possible use of " finisher " diets the time of changeover is of some importance.

This problem was recently examined in a trial conducted with 64 individually-fed Large White pigs drawn from the Experimental Farm herd. The experiment conformed to a $2 \times 2 \times 4$ factorial layout in which two diets were fed to equal numbers of hogs and gilts and examined in relation to four points of changeover from starter to finisher ration. The rations were compiled to ensure that the amino acid, mineral and vitamin status accorded with current recommendations, including adequate margins of safety where appropriate. The main features of the results are given in Table 2.

With reasonably late-maturing pigs it seems advantageous to increase dietary protein above the level commonly used, but unfortunately changes in body composition as revealed by dissection are not reflected in significant differences in " standard " measurements; this, however, is frequently the case and the value of dissection data in experimental work needs no elaboration. There was no significant influence of the time of changeover from one diet to another on the subsequent growth or

economy of food utilization but these traits, as do carcass data, consistently favour change at 100 lb. liveweight. Though the optimum may lie between 100—120 lb. there seems little virtue in a very prolonged starter period as practised by some feeders.

TABLE 2

EFFECTS OF DIETARY PROTEIN LEVEL AND WEIGHT AT CHANGEOVER FROM STARTER TO FINISHER RATION ON PIG PERFORMANCE

Performance characteristic	"Standard" Protein	"High" Protein	Liveweight at change (lb).			
			80	100	120	140
			mean of both diets			
Days to Grow:						
from 50 to 100 lb.	49.8	**47.2**	48.4	48.8	47.7	49.0
from 50 to 200 lb.	128.1	**123.1**	127.0	124.5	126.5	125.1
Food Consumption:						
from 50 to 100 lb.	155.1	**144.6**	152.9	149.1	147.9	149.2
from 50 to 200 lb.	553.7	**528.0**	548.7	532.3	543.8	538.6
Body length (mm.)						
(i) Pelvis-1st rib/sternum	796	805	797	810	799	797
(ii) Pelvis-Atlas	965	979	969	**992**	958	968
Backfat (mm.)						
(i) Shoulder	44.3	42.9	44.1	**41.8**	46.0	42.5
(ii) Loin	31.7	30.2	31.8	29.1	32.0	30.9
Weight (lb.) of:						
(i) Lean	34.2	**35.2**	34.8	35.0	34.5	34.5
(ii) Fat	24.5	**23.0**	24.6	**22.9**	23.8	23.7
(iii) Bone	7.72	7.97	7.94	7.97	7.58	7.89

N.B. Figures shown in heavy type denote differences significant at P=0.05.

Note: "Standard" Protein: 16% in the starter followed by 12% in the finisher rations.
"High" Protein: 19% in the starter followed by 14% in the finisher rations.

Changes in the supplies and prices of various feed ingredients in recent years have served to focus attention upon the feasibility of supplementing relatively simple formulations with synthetic amino acids and upon the use of so-called high-energy rations. These fields of study have already been extensively explored in chicken dietetics following particularly an increasing availability of cheaper sources of "feed-grade" fats. It has been clearly demonstrated that the food intake of birds is determined by dietary energy status[3] and that it is necessary to specify levels of all constituents in terms of energy. In contradistinction to poultry, however, it is uncommon for bacon pigs to be self-fed; in fact some scales of restricted feed input fall very far below appetite capacity. Nevertheless, the significance of feed energy variations are not fully appreciated, and Waddell[4], among others, considers that the problem of overfat carcasses might logically be examined from the standpoint of variation in dietary energy: protein ratios, rather than attempt its solution by implementing scales of feed restriction.

In a preliminary trial[5] in which high and moderate levels of energy content and protein were given in all combinations, the effect of energy *per se* on carcass characteristics was very evident. (Table 3).

TABLE 3

EFFECT OF DIETARY ENERGY LEVEL IN THE DIET ON CARCASS CHARACTERISTICS

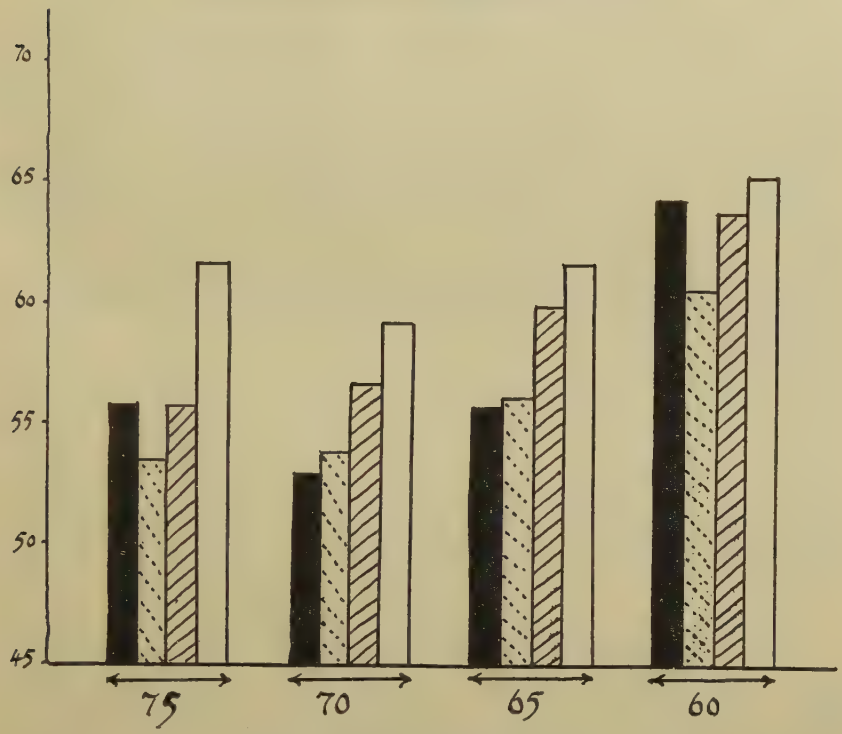
	Moderate Energy (66% T.D.N.)	High Energy (75% T.D.N.)
Body length (mm.)		
Pelvis-1st rib/sternum	805.9	788.6
Pelvis-Atlas	972.8	950.4
Backfat (mm.)		
Shoulder	46.1	48.1
Loin	25.8	30.6

Note: Protein levels were 15.5% and/or 18.5% in the starter phase followed by 13.5% and/or 12% in the finisher phase.

In this and a number of other studies it has become evident that the performance of the pig at any particular moment of time is a duality of its contemporary treatment and previous nutritional history. Problems arising from these influences are partially overcome by studies relating specifically to effects produced during the growth phase in question. A long-term project is currently in progress in which the potential inter-relationships of dietary energy and protein are being examined. In the growth phase a variety of dietary treatments are being followed by a common finisher diet, and subsequently, an optimal starter diet will be followed by a range of finisher diets. To date three replicates of a trial incorporating energy and protein levels as shown in the accompanying figure have passed the changeover point at 120 lb. Pigs on certain selected treatments are also being grown to slaughter weight in order to ascertain direct effects on carcass traits.

These results can at this stage yield only the most tentative conclusions, but it would appear that the optimum protein level lies between 16—18% and that there is little advantage in raising the energy level above 70% total digestible nutrients. Though the experimental design does not bear direct reference to energy : protein ratio, these data suggest that this factor is of little consequence in the early stages of growth. All growth trials are paralleled by metabolism studies which are used to provide data regarding both energy and nitrogen retention by the animal. The re-appearance of a vigorous manufacturing pig trade demands that more attention be focussed on the nutritional requirements of the animal under conditions of self-feeding. Housing facilities are soon to be extended so that problems relevant to these circumstances of management can be comprehensively examined.

EFFECT OF DIETARY ENERGY AND PROTEIN ON THE TIME TAKEN FOR PIGS TO GROW FROM 50 TO 120 LB.



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THE PLACE OF ARGININE IN POULTRY NUTRITION

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There are five amino acids which are usually recognised to impose a potential limit upon the productive efficiency of the broiler chick. When practical rations are devised to satisfy recommended nutrient allowances these five amino acids present difficulties in the attainment of the desired concentrations in the following order: methionine>lysine>arginine> tryptophan>glycine. A considerable amount of attention has been given to the supplementation of rations with methionine and lysine, the requirements for which are reasonably well established and there are few problems involved in supplementation. However, there is considerable uncertainty regarding the actual requirements of the broiler chick for arginine.

Almquist in 1950[1], using "synthetic" diets in which casein was the main source of protein, suggested that the requirement for arginine in the chick is 1.2% of the ration or 6% of the protein (with a ration of 20% protein). These values still tend to be accepted though subsequent studies have shown that the requirement can apparently vary considerably with the nature of the ingredients of the ration. Snyder and his colleagues[2] found a requirement for arginine of 1.7% of the ration when it was based on casein as the protein source whereas it was 1.1% when the ration was mainly composed of maize and soya bean meal. Krautmann[3] confirmed this value of 1.7% but quoted a figure as low as 0.9% for a ration of maize and soya bean. Connor Johnson and his colleagues[4] used a mixture of amino acids that simulated the composition of casein and confirmed the high level of arginine that is required in synthetic rations and stated that the optimum level was 2.0% of the ration.

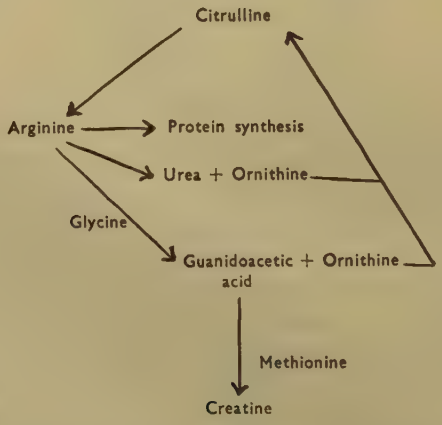

FIG. 1
METABOLIC PATHWAYS OF ARGININE (SCHEMATIC)

It is likely that the metabolic inter-relationships of arginine may have contributed to the confused observations with regard to dietary requirements. Arginine may arise from citrulline and may be involved in several metabolic pathways (Fig. 1.). Fisher[5] has discussed arginine as a precursor of muscle creatine and it is possible that there may be a particular requirement for arginine during the early life of the chick. There is only limited information available on the distribution in the fowl of the various enzymes associated with the metabolism of arginine and its derivatives.

The place of arginine in poultry nutrition has therefore been examined from two main points of view:

1. The growth rate of broiler chicks has been determined with rations of the type normally used in this country and the effect of supplementation with arginine and related compounds has been evaluated.

2. An examination has also been made of the distribution and properties of the enzymes associated with the metabolism of arginine in the organs of the chick. Particular attention has been given to the liver and kidney.

A series of rations were prepared that contained progressively decreasing quantities of protein and arginine. They followed a fairly normal pattern in relation to rations used in commercial practice in the United Kingdom. The major components and the protein and arginine contents of these rations are listed in Table 1. Some barley was introduced into the later rations and to limit the arginine content soya bean meal was largely replaced by corn gluten meal. In view of the known influence of amino acid balance upon growth performance[6] the arginine content is best expressed as a percentage of the protein (Table 1): in this series of experiments it varied from 5.8% to 3.8%, whereas 6% is usually regarded to be necessary to satisfy the requirements of the broiler chick.

As the protein contents of the basal rations was decreased (ARIA→AR5A, Table 2.) the live weight of chicks at the 6-week stage also decreased. In no treatment did the supplementation of the ration with arginine or any related compound lead to a stimulation of growth. Under these circumstances the protein level is probably the factor that limits growth. In experiment AR6 where both the protein and arginine levels are lower there is increased growth when the supplements are added. This suggests that when the ration contains 18% protein the requirement for arginine is less than 0.8% of the diet (or less than 4.4%

of the protein). A further series of experiments is now being conducted in which the protein content of the basal ration is held constant at 21% and the arginine content fluctuates within the range of 0.7% to 1.3%.

TABLE 1

COMPOSITION OF FIVE BASAL RATIONS USED IN DETERMINING THE REQUIREMENT OF THE BROILER CHICK FOR ARGININE

Component	Composition (%)				
	AR1	AR2	AR4	AR5	AR6
Wheat meal	34	40	43	45	46
Maize meal	29	29	20	20	23
Barley meal	0	0	12	13	11
Soya bean meal	18	18	0	0	0
Corn gluten meal	0	0	8	11	12
Fish meal	14	8	12	6	3
Minor supplements	5	5	5	5	5
Protein (% of ration)	24	22	20	18	16
Arginine (% of ration)	1.4	1.2	1.0	0.8	0.6
Arginine (% of protein)	5.8	5.4	5.0	4.4	3.8

TABLE 2

AVERAGE LIVE WEIGHTS OF CHICKS (g.) AT SIX WEEKS OF AGE

(Each figure represents the average of the mean for four groups of 10 birds)

Treatment*	Weight (g.)				
	AR1	AR2	AR4	AR5	AR6
A	862	873	805	697	606
B	850	867	799	696	650
C	848	865	815	692	699
D	881	847	789	687	653
E	821	862	781	680	688
F	840	873	793	681	685

* Treatments: A=Basal; B=Basal+0.2% arginine; C=Basal+0.2% glycine; D=Basal+0.2% arginine+0.2% glycine; E=Basal+0.2% guanidoacetic acid; F=Basal+0.2% creatine.

Arginase is an enzyme that catalyses the conversion of arginine into ornithine and urea. Since the chick does not excrete urea as a major end-product of nitrogen metabolism and there is little evidence to suggest that the chick requires ornithine it would seem that this is a wasteful pathway. The activity of arginase in the chick has, therefore, been examined. This has involved the establishment of the optimum conditions for its activity and the development of an assay technique. Rate of reaction has been determined by a measurement of urea production. The determinations were carried out at 37°C, an optimum pH of 9.5 was demonstrated, a Km value of 6.7×10^{-3}M has been found and the optimum circumstances for pre-incubation with co-factor have been defined.

In most mammalian species arginase activity is mainly associated with the liver but some activity is also found in the kidney (Table 3.). There is little arginase in chick liver but its activity in the kidney is comparable with that in other species. This can probably be correlated with the extent of urea excretion in avian species.

TABLE 3

ARGINASE ACTIVITY IN LIVER KIDNEY AND OTHER ORGANS EXPRESSED IN TERMS OF μ MOL. PRODUCT PER HOUR OF INCUBATION PER g. NET WEIGHT OF SAMPLE.

Species	Liver	Kidney	Spleen	Reference
Rat	20,000	3,000	1,200	(7)
	20,000	300	—	Determined
Chick	3	180	0	(7)
	400	3,000	—	Determined

The enzyme glycine transamidinase catalyses the formation of guanidoacetic acid from arginine and glycine. Its activity has been found to be considerably lower than that of arginase; using the same units as in Table 3 a value of 3 has been obtained for mammalian kidney and one of 0.01 for chick kidney. A radio-isotope technique will be used in an attempt to demonstrate the quantitative importance of this pathway. A third enzyme system, arginine synthetase, which effects the conversion of citrulline to arginine is also being examined.

It is intended that these observations should exemplify the theme that developments in experimental nutrition are dependent upon a combination of the study of dietary requirements and of the metabolic fate of specific nutrients.

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ASSAY OF AVAILABLE METHIONINE AND CYSTINE USING THE CHICK

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The nutritive value of a protein is determined not only by its amino acid content but also by the availability of the individual amino acids in the protein fed to the animal. Despite the considerable attention that is now given to the amino acid composition of the protein of pig and poultry rations it is seldom possible to state the proportions of the various amino acids which are available. Since processing and storage methods markedly influence amino acid availability[1] it is particularly important to carry out the determinations on the rations actually fed.

Methionine and lysine are the two dietary amino acids most likely to impose a limitation upon the growth performance of pigs and poultry. Information about the biological availability of these amino acids is therefore most necessary. Some techniques for the estimation of available lysine have seen suggested. Carpenter[2] has developed a chemical test that measures the extent to which the ϵ-amino group of lysine is not involved in a chemical bond. This seems to produce a value that is related to the availability of the amino acid but it does not take into account the other factors which can also modify availability. The results obtained by this technique must be regarded as maximum values. Elvehjem and his colleagues[3] have described a method based on a bio-assay procedure for determining the availability of lysine in rat diets. The same approach has also been used for examining the availability of lysine in bread[4]. It is, however, desirable that when information is sought regarding the availability of an amino acid in poultry rations that the determinations be carried out using the species to which it is intended that the ration should be fed.

No satisfactory procedure has been reported to assay sulphur-containing amino acids available to the chick but Schweigert and Guthneck[5] have described a method for the rat. This is a bio-assay technique in which the growth of the rats is measured and a basal diet containing casein treated with hydrogen peroxide fed as the main protein source. Unfortunately all the requirements of a satisfactory bio-assay technique were not demonstrated to have been met and availability, digestibility and faecal output were not clearly distinguished. It was assumed[4, 5] that the inclusion in the basal diet of additional protein from the test material did not modify the response to the limiting amino acid in the supplement. The recent work of Fisher[6] suggests, however, that the dilution of the test addition of the limiting amino acid in a greater dietary protein

content will alter the response. It is difficult to avoid such a dilution since the assay is made upon a material that contains protein. The cause of the altered response[6] could not be defined in precise terms: it appeared to be dependent upon the nature of the nitrogen-containing materials added.

A method has therefore been developed for the biological assay of methionine and cystine using White Leghorn chicks at 11 to 18 days of age. A basal diet is used to which various supplements are added and the response measured in terms of the growth rate and food consumption of the chick. The basal diet is composed of 50% maize starch, 35% extracted soya bean meal, 5% dried whey, 5% beef tallow and 5% mineral and vitamin mixture. All supplements made to the ration replace starch. Preliminary experiments led to the conclusion that 0.188% choline chloride and 0.2% glycine should also be included in all rations to eliminate any possibility of growth response to these components when they are present in test materials. This diet is deficient only in sulphur-containing amino acids and therefore the growth of the bird when an unknown protein is added should be related solely to its content of available sulphur amino acid.

There are, however, several preliminary features that must be established before accepting such a technique of bio-assay. The full requirements for growth of the species used must be known. The growth should be a function only of the nutrient that is omitted or limiting. The assay must be applicable over a wide range and a linear and parallel response should be obtained on the inclusion of graded amounts of the standard and test materials. A constant response is essential on repeated assay. All secondary limiting factors must be eliminated from the working range of the assay. The technique must be specific for the constituent examined and no partial replacements, complementary effects or antagonistic responses to other factors can be acknowledged.

Experimental work has been carried out to satisfy these constrictions as far as possible. It was first established that methionine and cystine were the only amino acids limiting growth and food utilization by supplementing the diets with all other amino acids singly and in groups, in the presence of more than sufficient methionine to correct the deficiency. A representative group of results is given in Table 1. When adequate methionine was present it was shown that growth was limited only by the protein or nitrogen content of the diet. A protein-deficient diet was deliberately chosen in order to maximise the overall response to methionine supplements when the requirement is expressed in terms of a

proportion of the protein. Such a form of expression probably eliminates problems introduced by the " dilution " of the limiting amino acid by the protein of the test material [6].

TABLE 1

SUPPLEMENTATION OF BASAL RATION WITH METHIONINE AND OTHER AMINO ACIDS SINGLY AND IN GROUPS

Treatment	Mean live weight (g., 9—20 days)	Food conversion ratio
	(S.E. ±2.0)	(S.E. ±0.07)
1. Control	57.4	2.90
2. +0.3% DL-Met	93.7	2.19
3. +0.3% DL-Met+Gly	93.2	2.13
4. +0.3% DL-Met+Lys	88.3	2.27
5. +0.3% DL-Met+Lys+Gly	95.0	2.17
6. +0.3% DL-Met+Lys+Gly+Leu	98.3	2.16
7. +0.3% DL-Met+Lys+Gly+Tyr	89.6	2.37
8. +0.3% DL-Met+Lys+Gly+Val	90.8	2.34

Met=Methionine; Gly=Glycine; Lys=Lysine; Leu=Leucine; Tyr=Tyrosine; Val=Valine.

All amino acids except methionine were in the l-form and added at a level of 0.2% of the ration. Each weight represents the mean of 3 replicates of 10 chicks.

TABLE 2

LIVE-WEIGHT GAIN OF CHICKS WHEN GRADED AMOUNTS OF METHIONINE ALONE AND METHIONINE WITH CYSTINE ARE ADDED TO THE BASAL RATION

Treatment	Mean live weight (g. from 9—15 days)	Food conversion ratio
1. Control	29.8	3.29
2. +0.01% DL-Met	29.7	3.24
3. +0.02% DL-Met	30.7	3.18
4. +0.04% DL-Met	34.4	2.97
5. +0.08% DL-Met	38.4	2.71
6. +0.16% DL-Met	43.6	2.43
7. +0.32% DL-Met	45.5	2.29
8. +0.64% DL-Met	44.2	2.28
1. Control	33.0	3.14
2. +0.4% L-Cys	41.7	2.42
3. +0.4% L-Cys+0.01% DL-Met	45.1	2.29
4. +0.4% L-Cys+0.02% DL-Met	48.6	2.22
5. +0.4% L-Cys+0.04% DL-Met	52.5	2.13
6. +0.4% L-Cys+0.08% DL-Met	55.7	2.03
7. +0.4% L-Cys+0.16% DL-Met	55.6	2.07
8. +0.4% L-Cys+0.32% DL-Met	54.0	2.10

Met=Methionine; Cys=Cystine.

Each weight represents the mean of 3 replicates of 10 chicks.

It was established that the growth of the birds was a function of added methionine. Graded levels of DL-methionine were added to correct for the known deficiencies of both methionine and cystine. A linear

relationship was found between the growth of the birds and the logarithm of the supplementary additions of amino acid within the range of 0.04 to 0.20% of the diet (see Table 2). It is recognised that methionine will always satisfy a requirement for cystine but that the reverse is not true. Therefore in the presence of excess cystine (0.4%) a bio-assay technique can be established for methionine. Under such circumstances a linear response in terms of growth is found with supplements of DL-methionine within the range 0.01 to 0.08% (see Table 2).

Using these two basic diets it has proved possible to effect a bio-assay for available sulphur amino acids (methionine and cystine) and available methionine, each in terms of methionine. Preliminary assay results suggest high levels of availability of the methionine in casein and standard soya bean meal whilst the available cystine content of the latter appears to be low. Methionine and cystine in purified soya protein appear to be less available than in the natural products. These results require confirmation.

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THE DIFFERENTIAL CHARACTERISTICS OF EARLY AND LATE ADOPTERS OF FARMING INNOVATIONS

Gwyn E. Jones

Most innovations which are available to farmers for adoption into their production operations are the result of organised research and development. They originate mainly from research conducted by Universities and by public or private research organisations, while their development depends on commercial firms which recognise in them a profitable business proposition.

The effort directed into the research and development of farming innovations would be largely frustrated if farmers did not adopt them. The adoption of such innovations by individual farmers usually follows an adoption process[1] which may be briefly summarised as follows:— (i) A farmer becomes aware of the existence of an innovation, or he recognises the need for it[2]; (ii) he displays an interest in the practice— this may be accompanied by seeking or accepting relevant information and advice, and observing its use elsewhere; (iii) the innovation is mentally evaluated by the farmer in terms of his scale and system of farming; (iv) the practice is accepted on a trial basis; and (v) its complete adoption by the farmer into his farming system.

A time lag invariably occurs between the initial availability of an innovation and its widespread adoption. In addition to the fact that all farmers do not become aware of a particular practice simultaneously, the length of the adoption process and of the stages within the process varies among farmers. Ryan and Gross[3], in their classic study of the diffusion of hybrid corn in Iowa, have shown how a group of farmers who adopted the seed soon after its introduction passed through the adoption process in slightly over one and a half years, compared with over nine years taken by the late adopters.

The adoption of a new practice among farmers thus proceeds over a period of time, the length of this period being dependent upon the nature of the practice and on the time spent by individual farmers in the earlier stages of the adoption process. It is the purpose of this article to show that farmers who adopt agricultural innovations relatively soon after their introduction (the "early" adopters), differ in certain economic, social and personal characteristics from those who delay in adopting them (the "late" adopters).

Agricultural equipment and materials are the tangible traits of production techniques at any time and place. As with cultural traits, it can be demonstrated that the number of farmers adopting new practices describes an S-type curve when plotted cumulatively against time. The frequency distribution of farmers who adopt particular innovations during each unit of time (say, annually) thus approximates to a normal curve. On this basis, early and late adopters may be distinguished as those farmers who occupy positions at each "tail-end" of the curve[4].

The adoption of 21 new practices by a sample of 52 East Midland farmers has been investigated. These farmers all practised a mixed system of farming and the innovations chosen were applicable to a range

of farm enterprises. The earliness or lateness of individual farmers in adopting each innovation has been assessed by expressing the date of adoption in terms of the number of standard deviations from the mean adoption date for that practice by the entire sample of farmers. A negative standard deviation indicates relatively early adoption, a positive standard deviation a late adoption. The " standard deviations " of each farmer for the practices which he has adopted have in turn been averaged, and these mean values have been weighted by the number of practices adopted. This provides a measure of the average earliness or lateness of each individual farmer in his behaviour regarding the adoption of a group of agricultural innovations. The distribution of this measure for all farmers in the sample describes a curve which does not differ significantly from a normal distribution. The first and last 27% of the adopters (14 early and 14 late adopters) have been withdrawn from the total sample in order to test for the differential characteristics of each sub-group.[5]

It may be postulated that early adopters within the sample will be high adopters of new farm practices at any particular point in time, and that late adopters will be low adopters. That is, since early adopters, by definition, exhibit a behavioural tendency to adopt innovations soon after they become available, at any one time they may be expected to have adopted a high proportion of new practices and techniques which are applicable to them. On the other hand, late adopters accumulate a back-log of unadopted practices which they will tend to adopt before more recent innovations. The association of early with high adoption, and of late with low adoption, is shown in Table 1.

TABLE 1

DIFFERENTIAL ADOPTION OF NEW FARM PRACTICES IN 1959 BY EARLY AND LATE ADOPTERS

Total Adoption of New Farm Practices (1)	Early Adopters		Late Adopters	
	No.	%	No.	%
Low	0	0	12	85.7
Medium	1	7.1	2	14.3
High	13	92.9	0	0
TOTAL	14	100.0	14	100.0

(1) A heuristic division based on an index of new practices adopted for individual farmers.

Ten characteristics have been selected in order to test whether there are differences between early and late adopters.

TABLE 2

CHI-SQUARE TESTS OF SELECTED DIFFERENTIAL CHARACTERISTICS OF EARLY AND LATE ADOPTERS

	$x^2 =$	DF	P<
Economic Characteristics: (1):			
Total Gross Income	8.44	2	0.02
Management and Investment Income (2)	3.16	2	0.30
Net Family Income (3)	2.71	2	0.30
Farm Size	4.10	2	0.20
Social and Personal Characteristics of Farmer:			
Age	12.30	2	0.01
Education (4)	10.44	3	0.02
Social Origin	4.32	2	0.20
Total Social Participation (4)	2.97	2	0.30
Agricultural Education	1.40	1	0.30
Use of Information and Advice (4)	1.06	2	0.70

(1) Average 1954/55 to 1958/59
(2) Gross output less total inputs (including all family labour)
(3) Gross output less inputs (excluding all family labour)
(4) Based on indices

Early adopters (Table 2) are distinguished from late adopters by a significantly higher average gross income. Of the fourteen early adopters, nine obtained an average annual gross income for the period 1954/55 to 1958/59 of £12,000 and over; only two of the fourteen late adopters attained this level of turnover. A tendency also exists for early adoption to be associated with relatively high average management and investment incomes and average net family incomes, and with a large farm size.

Among the social and personal characteristics of the farmers investigated, age and education are significantly associated with earliness or lateness in adoption behaviour. The majority of early adopters are under 45 years of age and have received a formal education beyond the School Certificate (Ordinary level G.C.E.). By contrast, almost all the late adopters are 45 years of age or over and they left school before or immediately after taking their School Certificate. Early and late adopters cannot be distinguished according to whether or not they have received any vocational education in agriculture.

The time of adoption of farming innovations does not differ according to the social origin of the farmer or his participation in social activities, nor to the use he makes of information and advisory sources. Late adopters tend to be farmers' sons to a greater extent than early adopters. Although this difference is not statistically significant, it may indicate a certain degree of inbred resistance to change, particularly among older farmers, until an innovation has become well-established

and commonly accepted. Early adopters also tend to be more active in their participation in community and farming affairs but, again, the tendency is insufficient to establish this as an incontrovertible characteristic of the group.

The similarity of early and late adopters in their use of information and advisory sources is to some extent illusory. It arises largely from the composite nature of the measure for this trait. Distinct differences do occur in the sources from which early and late adopters state they would seek information and advice on five types of farming innovations (Table 3).

It is significant that both early and late adopters make use of dealers, merchants, salesmen, etc., to an approximately similar extent, and these three, considered as a single group, form the most important source of information and advice. Early adopters, however, rely to a greater extent than late adopters on personal reasoning, past experience and observation as aids in making decisions regarding new farm practices. Relatives and neighbours are of greater importance as sources of information and advice to late adopters; this factor necessarily retards the adoption process. On the other hand, early adopters make relatively more use of reading material and formal advisory sources (such as the N.A.A.S.) than the late adopters.

TABLE 3

PERCENTAGE OF RESPONSES ON SOURCES OF INFORMATION AND ADVICE WHICH EARLY AND LATE ADOPTERS STATED THEY WOULD USE FOR FIVE TYPES OF FARMING INNOVATIONS

Source of Information and Advice	Early Adopters %	Late Adopters %
Dealers, Merchants, Salesmen, etc.	43.5	45.3
Personal reasoning, past experience or observation	37.3	31.5
Relatives or Neighbours	9.5	19.3
Formal Advisory Agencies	7.3	3.1
Reading material	2.4	0.8

In summary, those farmers who appear most ready to adopt farming innovations are generally young, possess a relatively high level of general education and operate large farm businesses. Further, although formal agencies and reading material form a relatively minor source of information and advice for all farmers, the early adopters make greater use of such sources than their more conservative colleagues. This undoubtedly influences their pattern of behaviour regarding new practices since it gives weight to their personal reasoning and observation.

The results of adopting innovations at an early date after their introduction are largely economic. Innovations, which are commercially acceptable, increase output and/or lower production costs. Thus, early adopters enjoy an economic advantage over late adopters; the widespread adoption of an innovation may lead to lower prices for all producers of the commodity concerned, but over the entire adoption period, the early adopters will gain a higher net profit than the late adopters. At the same time, the early adopters bear higher degrees of uncertainty and risk regarding the technical and economic benefits to be derived from an innovation. It is possible that the predominantly large size of farm business, which is associated with early adoption, reduces the relative magnitude of the risk element involved in adopting farm innovations soon after they become available. The social and personal characteristics which distinguish the early from the late adopters, however, are also important in explaining the different behaviour of the two groups.

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THE WEATHER IN 1960

T. Webster

General

The main feature of the year was the very high rainfall; it was 42% above average and more than twice that of 1959. Despite this, the area generally escaped the worst excesses of the weather which affected other parts of the country although there was some local flooding. The year was rather dull with temperature slightly above average. There were few fogs, no really severe frosts, and the small falls of snow which occurred were confined to the early part of the year.

Rainfall

Over the country, it was the wettest winter (December, 1959, to February, 1960) since 1915-16, while locally the annual rainfall had not been exceeded for at least the past fifteen years. After an extremely wet January, there followed four months with rainfall below average, April and May being particularly dry. From then on every month was wetter than average, although June was, in fact, an excellent month for weather, the high monthly rainfall total being the result of a few days of heavy rain. October was particularly unpleasant, with both the highest rainfall and the highest number of rain days, while from June to October the total rainfall was over 80% greater than normal.

Sunshine

The pattern of the sunshine figures was roughly the inverse of that for rainfall, except for June and December, the only two months with sunshine much above average. June was brilliantly sunny and, although being the month with normally most sunshine, it had the second highest relative figure for any month; the total hours of sunshine for June had not been exceeded for at least fifteen years. January, March and October were particularly dull.

Temperature

During the first six months the monthly mean screen temperature became almost progressively higher than average and reached a peak in June. Conditions were also fairly mild during the last three months, but the cool weather during July, August and September was sufficient to bring the yearly average down almost to normal. Soil temperatures followed a very similar pattern.

Crops

Conditions during the earlier part of the year were in many ways similar to those of 1959. Once again snow cover during the severest weather prevented more than slight damage to winter crops. Early sowing conditions were very good and again some corn was sown in February. Moderate rainfall in May, however, gave much better growing conditions than in 1959, and establishment of most crops was excellent. Potatoes were almost undamaged by frost, despite early planting and emergence, and bolting in beet was negligible.

Some incipient drought effects were seen in June, particularly in potatoes, and irrigation was started, to be followed almost immediately by nearly 2 inches of rain in 24 hours. The equipment was not seriously in use again in 1960. The continuing wet weather produced vigorous, sometimes rank, crops and there was some lodging in cereals, beans and kale. Cereal mildew was not excessive and only traces of yellow rust were observed. Virus yellow of beet appeared in early July and increased considerably, but did little to check the vigour of the crop. Potato blight was first seen early in August and, as was to be expected, defoliation was rapid and three weeks later was almost complete.

The harvest was extremely trying and prolonged. Locally, corn in stook was still out in November and some potatoes and sugar beet remained unlifted at the end of the year. Yields were good but quality often poor. Sprouted grain was common. Potatoes were considerably affected by blight, and often by scab, despite the wet summer. Sugar content of beet was low. Fodder crops, particularly silage maize, gave high yields. This was unexpected but was probably due to the excellent growing conditions in June.

Delays in ploughing and winter sowing were very common, but absence of severe weather enabled even quite late sowings to establish well.

WEATHER DATA FOR 1960

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR
A. Rainfall (inches)	4.20	1.46	1.30	.99	1.24	2.61	3.31	3.70	3.88	4.65	2.61	2.65	32.60
Rainfall as % of average 1916-1950	193	87	92	59	67	180	140	168	209	218	119	137	142
No. of times rainfall exceeded in previous 15 years	0	9	8	11	12	6	2	5	1	1	3	2	0
No. of rain days	21	14	12	11	6	7	17	18	15	25	21	14	181
Rain days as % average 1946-1960	139	110	93	99	50	52	137	129	112	194	142	90	113
B. Total sunshine (hours)	26.0	60.4	57.9	143.8	186.8	265.4	139.1	144.9	108.4	47.0	57.2	46.9	1283.8
Sunshine as % of average 1921-1950	63	101	54	103	106	140	77	89	88	49	106	147	94
No. of times sunshine exceeded in previous 15 years	14	7	15	8	6	0	13	9	10	15	4	3	11
C. Mean daily radiation (mw-hr. cm^{-2} day^{-1})	45	112	157	314	420	526	394	341	224	98	92	71	233
D. Temperature (°F)													
(1) Mean screen maximum	43.7	44.5	49.0	56.6	63.4	71.1	68.0	67.8	62.1	55.4	50.7	43.5	56.4
(2) Mean screen minimum	34.5	33.5	37.4	39.8	44.7	50.1	50.8	49.9	45.9	43.7	38.7	33.9	41.9
(3) Average of (1) and (2)	39.1	39.0	43.2	48.2	54.1	60.6	59.4	58.9	54.0	49.5	44.7	38.7	49.1
(4) Deviation from average 1921-1950	+0.7	+0.1	+1.0	+1.5	+2.1	+3.0	−2.2	−1.6	−2.3	−0.1	+1.7	−0.3	+0.2
(5) Soil temperature at 4″	38.1	36.9	40.4	46.4	54.6	62.4	60.3	58.4	54.3	49.4	43.6	38.4	48.6
(6) Deviation from average 1946-1960	+0.9	+0.1	+1.0	+1.2	+2.2	+3.8	−1.3	−1.7	−1.4	+0.2	+0.5	−0.9	+0.4
(7) Soil temperature at 8″	39.6	38.3	41.5	46.1	53.5	61.1	59.7	58.5	55.3	50.5	45.1	40.0	49.1
(8) Deviation from average 1946-1960	+1.3	+0.5	+1.3	+0.8	+1.7	+3.6	−1.2	−1.5	−1.2	+0.1	+0.6	−0.6	+0.4
(9) Soil temperature at 2′	43.0	41.4	43.3	46.6	52.0	59.0	59.7	59.4	57.9	52.9	48.3	44.1	50.6
(10) Deviation from average 1946-1960	+2.4	+1.9	+1.7	+0.3	+0.3	+1.7	−1.2	−1.5	−0.5	−0.1	+1.0	−1.0	+0.5

UNIVERSITY OF NOTTINGHAM
SCHOOL OF AGRICULTURE

PUBLICATIONS
1960

AGRICULTURAL BOTANY

D. ASPINALL

An analysis of competition between barley and white persicaria. II. The course of competition. *Ann. appl. Biol.* **48**: 637-54. (1960).

The responses of plants of white persicaria growing in competition with barley are typically those of shaded plants and the amount of light penetrating the stands is reduced to the level where these responses would be expected. Nevertheless, when the effects of root and shoot competition were separated, the former was much greater. It appeared that restricted nutrient supply first decreased the growth of persicaria and the divergence of growth led to these plants becoming progressively more and more shaded; ultimately there were direct effects of light on root expansion and later on leaf expansion. Mineral nutrients appeared always to be the factor in shortest supply.

M. N. BORAH, R. L. BURT, D. W. R. HEADFORD, F. L. MILTHORPE and E. M. SADLER

Growth of the potato plant. *Ann. appl. Biol.* **48**: 433-34. (1960).

A summary of a paper given to a meeting of the Association of Applied Biologists bringing together the results of several investigations on the potato.

F. L. MILTHORPE

Water relationships of plants in arid and semi-arid conditions. *Nature,* **185**: 435-36. (1960).

A brief account of a symposium on this topic organized by Unesco at Madrid in September, 1959.

The income and loss of water in arid and semi-arid zones. In *Plant-water relationships in arid and semi-arid conditions. Reviews of Research.* pp. 9-36. Unesco, Paris. 1960.

A comprehensive assessment of the factors influencing the supply of water to plants and their relative importance. Chapters include water increase from precipitation, dew and fog; factors influencing evaporation; methods of estimating evaporation; water loss from vegetables, estimation of soil water balance; assessment of climatic zones.

Review of *Crop Production and Environment* by R. O. Whyte. 2nd. ed. 1960. In *Field Crop Abstr.* **13**: 324-25. (1960).

T. H. NICOLSON

Mycorrhiza in the Gramineae. II. Development in different habitats, particularly sand dunes. *Trans. Brit. mycol. Soc.* **43**: 132-45. (1960).

In the course of ecological studies, mycorrhiza was noted to be widespread in grasses from many different habitats and communities. Detailed studies in sand dunes showed that the incidence of infection fluctuated according to the colonization zone.

Survival, colonization and antagonism of induced mutants of *Chaetomium globosum* Kunze. *Plant Dis. Reptr.* **44**: 774-77. (1960).

Induced mutants of *Chaetomium globosum* showed different abilities to survive in and colonize cellulose substrates in non-sterile soil. None, however, surpassed its parent in these capacities. Most mutants reduced the pathogenicity of *Helminthosporium victoriae* on oats but only one approached the antagonism shown by the parent line.

AGRICULTURAL CHEMISTRY

E. A. N. GREENWOOD and E. G. HALLSWORTH

An evaluation of the maximum radius of the rosette as a growth index for subterranean clover. *Plant & Soil* **12**: 49-56. (1960).

The maximum radius of the rosette, defined as the distance from the centre shoot to the base of the leaf furthest from it, is highly correlated with yield of dry matter (r=0.98 to 0.93) over the earlier vegetative period, but becomes progressively less sensitive as flowering approaches. The maximum radius was tested for fidelity as a rapid index of dry-matter yield using data from other factorial experiments. It proved satisfactory in nutrient experiments for comparing treatment means prior to harvesting, provided that correlation at harvest was greater than r=0.85. The limitations of the index are discussed.

Studies on the nutrition of forage legumes. II. Some interactions of calcium phosphorus, copper and molybdenum on the growth and chemical composition of *Trifolium subterraneum* L. *Plant & Soil* **12**: 97-127. (1960).

A study has been made of specific effects and interactions of Ca, Cu, Mo, and P on the symbiotic system and chemical composition of subterranean clover grown in sand culture under glass on high and low nitrate supply. The levels of Ca and Cu were low while those of Mo and P were in general high or excessive. N_2-fixation appeared to be specifically inhibited by deficiencies of Ca or Cu but was affected by Mo and P according to their effect on yield. The classic symptoms of Ca- and Cu-deficiencies were obtained on high-nitrate plants, but in symbiotic plants they appeared as symptoms of N-deficiency. This was confirmed by chemical analysis. The main yield interactions were Ca x Cu, Ca x P and Cu x P which were explained by the chemical data. Toxic effects of excess P which were observed were relieved by the increased growth rate associated with higher levels of nitrate or Ca, but were intensified by increased levels of Cu. Higher levels of nutrient-P enhanced equally the Cu- and Mo-content of tops. Copper deficiency depressed the uptake of Ca into the tops.

E. G. HALLSWORTH, S. B. WILSON and E. A. N. GREENWOOD

Copper and cobalt in nitrogen fixation. *Nature, Lond.* **187**: 79-80. (1960).

Subterranean clover grown in sand culture on a modified Long Ashton nutrient medium was supplied with Cu at six levels (0.000064—6.4 ppm.) of Cu or with Co (0.0006—0.6 ppm.). N fixation was stimulated when 0.64 ppm. of Cu was supplied, and also with 0.006 and 0.06 ppm. of Co. The effect of these additions on the amount of haem in the nodule is noted.

D. LEWIS

Ed. *Digestive Physiology and Nutrition of the Ruminant. Proc. Univ. Nottingham 7th Easter Sch. Agric. Sci.* Butterworths Scientific Publications, London. (1960).

See article elsewhere in this volume.

The fate of nitrogenous compounds in the rumen. *Proc. Univ. Nottingham 7th Easter Sch. Agric. Sci.*: 127-39. (1960).

Protein that enters the rumen is broken down into peptides, amino acids and ammonia. Some of the non-protein materials are synthesised into microbial protein. Both intact dietary protein and that within the micro-organism passes along the alimentary tract. The balance of breakdown and synthetic reactions in the rumen is governed by the solubility of the protein and the amount of carbohydrate material present. An assessment of the nutritive value of a protein depends on measuring the proportion of food protein converted to microbial protein, the relative nutritive values of these two types of protein, and the proportion of nitrogenous materials absorbed from the rumen and lost as urea. When absorbed ammonia becomes toxic, the acid-base status and electrolyte balance of the animal are distributed but probably do not account for all the signs of toxicity. The pattern of cellular migration of potassium during ammonia poisoning is important.

Ammonia toxicity in the ruminant. *J. agric. Sci.* **55**: 111-17. (1960).

The normal level of blood ammonia in the sheep is somewhat higher than in non-ruminants. Under conditions of ammonia toxicity the concentration in blood increases five- or six-fold. The toxicity of ammonium acetate, ammonium chloride and urea placed in the rumen follows different metabolic pathways. With the chloride there is an uncomplicated metabolic acidosis and with the acetate there is a respiratory alkalosis. These effects and the changes in the acid-base status do not account for the toxicity, which is probably due to a direct effect of the level of the circulating ammonium ions. The organisms within the rumen reach a maximum level of adaptation within 7 days and deal with large quantities of ammonia by a synthetic pathway. The intravenous administration of *e*-arginine does not markedly ameliorate ammonia toxicity.

The absorption of subcutaneously implanted thyroxine in the sheep. *J. agric. Sci.* **55**: 408-11. (1960).

Pellets of *e*-thyroxine (30 mg.) were implanted subcutaneously and the loss in weight of the implants and the plasma protein-bound iodine (PBI) level determined. The PBI concentration increased within a few days from a normal value of around 5 μg. per 100 ml. to one of 15-20 μg. per 100 ml. After 10-20 days the concentration slowly returned to normal and at 70 days was only slightly above the normal level. Within 4 weeks approximately 30% of the implant was absorbed; the pellet remained reasonably constant in weight thereafter.

I. H. RORISON

Some experimental aspects of the calcicole-calcifuge problem. I. The effects of competition and mineral nutrition upon seedling growth in the field. *J. Ecol.* **48**: 585-99. (1960).

The two calcicoles *Scabiosa columbaria* L. and *Asperula cynanchica* L. and the two calcifuges *Holcus mollis* L. and *Galium saxatile* L. are known from field observation to be highly exclusive in their distribution. To discover the primary factors determining this exclusiveness, seed of each species was sown into an acid Greensand, a calcareous sand and a chalk soil, both in the presence and absence of existing vegetation. Various combinations of calcium (as $CaSO_4$ $2H_2O$). potassium (as KCl) and phosphorus (as $Ca[H_2PO_4]_2H_2O$) were added to the soils. Results were expressed as percentage seedling survival, plant dry weight, and calcium, potassium and phosphorus per plant. There was a crucial phase during seedling establishment when chemical factors exerted a dominant influence compared with the physical nature of the soil and with competition. The nature of this chemical influence was considered.

Some experimental aspects of the calcicole-calcifuge problem. II. The effects of mineral nutrition on seedling growth in solution culture. *J. Ecol.* **48**: 679-88. (1960).

Seedlings of *Scabiosa columbaria* L. were grown in (a) inorganic solutions of varied pH, calcium and iron concentrations, and (b) in field soils which were considered to be toxic or deficient in respect of chemical constituents. Neither inorganic solutions of the pH values of soils used in the field nor a hundred-fold range of calcium-ion concentration had the drastic effect of the acid soil solution which produced symptoms of root inhibition seen in the field. These symptoms could also be induced in acid inorganic solution by the addition of an aluminium salt. Aluminium was detected in the soil solution and the inhibition was removed by raising the pH of each solution. This supported the view that it was aluminium in the ionic form which was toxic and that it was this element which was the primary cause of the exclusion of *Scabiosa* from the acid Greensand soil investigated. Some experiments with *Holcus mollis* L. are also described.

AGRICULTURAL MICROBIOLOGY

A. SEAMAN

A soft root-rot of *Linum usitatissimum* caused by a *Pseudomonas* sp. *Plant Dis. Reptr.* **44**: 214-15. (1960).

An outbreak of root-rot in flax seedlings, due to an organism similar to *Pseudomonas fluorescens*, was controlled by tetracyclines.

P. ANN TURBUTT, A. SEAMAN and M. WOODBINE

Microbiological aspects of the thermoduric *Microbacterium* genus. *Dairy Sci. Abstr.* **22**: 543-48. (1960).

A review of the general importance of these thermoduric organisms; their source; the inhibitory effects of raw milk on them; their detection and elimination; with a bibliography of about 100 references.

P. WIX

Mycological synthesis of fat from whey. II. Comparative studies with shaken and stationary cultures using selected moulds. *J. appl. Bact.* **22**: 175-83. (1959).

Using *A.ustus*, *P.oxalicum*, *P.frequentans* and *P.notatum* in media with the addition of ammonium sulphate, it was found that *A.ustus* would use up to 96% of the lactose and gave a mycelial felt with 13% protein and 28% fat.

M. WOODBINE

Fat production by micro-organisms. *Rep. Progr. appl. Chem.* **44**: 343-49. 1960 (1959).

A review of the potential applications of algae, bacteria, moulds and yeasts in producing fat, complete with about 50 references and a supplementary sectional bibliography.

AGRICULTURAL ZOOLOGY

W. N. YULE

Dieldrin lattices applied by aircraft for controlling hoppers of the red locust *Nomadacris septemfasciata* Serville. *Bull. ent. Res.* **51**: 441-60. (1960).

Trials of dieldrin insecticide applied lattice-wise to vegetation over hopper-infested areas were made in the Rukwa outbreak of the red locust in S.W. Tanganyika during 1958 and 1959. The results of these trials are discussed and the aerial dieldrin lattice method is compared with the best previous ground method of hopper control. It is shown that the new method is cheaper, more effective, and more practicable than the old method, besides enabling fuller aircraft utilization and further simplification of organisation to be obtained.

AGRICULTURE

J. D. IVINS

Digestibility data and grassland evaluation. *Proc. 8th Int. Grassland Cong. 1960.* 459-61 (1961).

The digestibility of herbage. an indication of its nutritive value, proved unaffected by animal characteristics. Dairy cattle, regardless of breed or level of milk production, and sheep, digested similar herbage to virtually the same extent, while characteristics of the livestock greatly influence animal production in terms of milk yields or liveweight gains from pasture. In consequence it is submitted that total yields of digestible organic matter and its constituents offer a means of comparing grassland treatments, uncomplicated by the variability in livestock or stocking rates.

T. D. BURGESS and G. E. LAMMING

The effect of hormones on growth rate and carcass quality of fattening lambs and hoggets. *Anim. Prod.* **2**: 83-92. (1960).

The influence of an implant of 12 mg. of diethylstilboestrol was studied in male suckling lambs and fattening male hoggets. In suckling lambs treatment did not significantly increase the rate of gain nor affect the carcass characteristics studied. In hoggets treatment produced a highly significant increase in rate of gain (33%); in pelt weight up to 2 lb., and a highly significant decrease in the amount of fat in the last rib. Carcass score and dressing percentage were not affected.

The effect of diethylstilboestrol, hexoestrol and testosterone on the growth rate and carcass quality of fattening beef steers. *Anim. Prod.* **2**: 93-103. (1960).

The effect of diethystilboestrol orally or diethylstilboestrol, hexoestrol and testosterone as implants, was studied in fattening beef steers. Treatment produced a highly significant increase in gain with no differences in carcess yield and carcass quality. The thyroid, adrenal and pituitary glands of treated and non-treated animals were compared. It was concluded that sex-hormone treatment leads to mild hyperthyroidism which may account for part of the extra growth.

G. E. LAMMING, R. M. STOKES and G. D. HORSPOOL

The influence on growth rate and slaughter characteristics of implanting fattening male hoggets with various levels of hexoestrol and diethylstilboestrol. *Anim. Prod.* **2**: 197-208. (1960).

In three trials involving 288 hoggets the influence of hexoestrol and diethylstilboestrol was compared. It was concluded that after approximately 140 days the influence of implantation had largely disappeared, 100 days before slaughter being the optimum time for treatment.

Diethylstilboestrol and hexoestrol implantation resulted in respectively an extra 4.7 and 6.1 lb. full liveweight, 3.7 and 5.3 lb. empty liveweight and 1.3 and 2.8 lb. extra carcass weight. Hormone uptake from a 12 mg. tablet of diethylstilboestrol was estimated at 39 micrograms per day between 30 and 200 days after implantation.

A. W. J. BROOME, G. E. LAMMING and WENDY SMITH

Studies on the relationship between ovarian hormones and uterine infection. IV. The role of the granulocyte system in uterine defence. *J. Endocrin.* **19**: 274-81. (1959).

Experiments to determine the role of the granulocyte system in uterine defence against bacterial infections have given the following results:

(1) There were significant differences in the bacterial content of the uteri of oestrous and pseudopregnant rabbits as little as 2 hr. following experimental infections. The uterus of oestrous animals was almost sterile 24 hr. after such infections but, at this time, the uterus of pseudopregnant animals still contained some residual infection.

(2) Ligation of the uterus in oestrous animals impeded drainage and prevented the escape of leucocytes and bacteria from the lumen. The leucocytes accumulated to form a sterile pyometritis similar to that observed in the non-ligated uterus of the pseudopregnant rabbit.

(3) Mobilization of leucocytes occurred more rapidly in the uterus of the oestrous animal, and it was also shown that a highly significant negative relationship existed in oestrous animals between bacterial numbers and leucocyte numbers within the uterus following experimental uterine infections. The slower rate of leucocyte mobilization in pseudopregnant animals is thought to be the main factor responsible for the different bactericidal activities of the uteri of oestrous and pseudopregnant rabbits.

R. B. HEAP and G. E. LAMMING

Studies of the uterine environment of different species. I. Influence of ovarian hormones on the chemical composition of uterine secretions. *J. Endocrin.* **20**: 23-4. (1960).

Studies have been completed to compare the organic and inorganic composition of uterine secretions from the sheep, rat, rabbit and cow. In the first three species the influence of hormones on the composition of secretions have also been studied in ovariectomised animals. In the rat there was significantly greater concentration of several constituents at oestrous and under the influence of oestradiol (Na, K, Cl, N, CHO). In the rabbit and sheep several constituents were significantly increased during the luteal phase or under the influence of progesterone (K, P, N and CHO).

G. E. LAMMING and R. B. HEAP

Studies of the uterine environment of different species. II. The influence of ovarian hormones on experimental uterine infections. *J. Endocrin.* **20**: 24-5. (1960).

Comparisons are made of the influence of hormones on resistance to experimental uterine infection in the rat, rabbit, sheep and cow. The uterus of the sheep proved resistant to infection irrespective of stage of cycle. The rabbit and cow proved susceptible to infection during the luteal phase but resistant at oestrous. The rat proved susceptible to uterine infection at oestrous. These reactions are related to the presence or absence of an acid-soluble fraction in the uterine secretion which appears to modify the granulocyte response of the uterus to experimental infection. Two mechanisms are probably involved in the different bactericidal activity of the rabbit uterus:

(a) The rate of leucocyte infiltration into the uterus.

(b) The activity of leucocytes within the uterus.

M. PATRICIA GRANT, R. B. HEAP and G. E. LAMMING

Studies of the uterine environment of different species. III. Influence of ovarian hormones on the development of ova in the ligated uterus of the rabbit. *J. Endocrin.* **20**: 25-6. (1960).

Comparisons are made of the growth of ova transplanted 2½ days postcoitum from donors into ovariectomised receptors which have been treated with various ovarian hormones. The ova were placed in ligated uteri and removed for examination after a further two days. The majority of ova increased in size in all groups but development was maximum in pseudopregnant animals. In the ligated uteri of oestrous, oestradiol-treated and progesterone-treated spayed animals there was a marked accumulation of a secretion which was different from the original environment and may have accounted for the development of these ova.

D. M. ALLEN and G. E. LAMMING

The induction of breeding activity in lactating ewes during anoestrus, *J. Reprod. & Fertil.* **1**: 213-22. (1960).

Forty lactating ewes were used in experiments to compare reproductive phenomena when they were slaughtered:

(1) during normal anoestrus (control),

(2) after breeding activity had been induced by a series of three intra-muscular injections of 50 mg. of progesterone (in oil) at 3-day intervals, followed after 48 hr. by a subcutaneous injection of 750 i.u. of P.M.S.

(3) after breeding activity had been induced, in response to the animals' endogenous endocrine secretions, by artificially manipulating the diurnal light : dark ratio.

Untreated control ewes showed no evidence of recent ovulations but a degree of ovarian activity was present as measured by the number of medium-and large-sized ovarian follicles.

Injections of progesterone and P.M.S. induced ovulation in nineteen of the twenty ewes treated and oestrus accompanied ovulation in twelve ewes. However, in ewes which mated there was a complete failure of fertilization which could not be attributed to poor semen quality. Manipulation of the diurnal light : dark ratio induced ovulation in all ten treated ewes and oestrus was observed in nine ewes. Oestrus was preceded by a "silent heat". The response of this form of treatment was slow but uniform. Of the ova recovered 41.2% were cleaving. A semi-quantitative estimate of the potency of total gonadotrophin in the anterior pituitary gland indicated a significantly higher level of gonadotrophin in untreated control ewes than in ewes which ovulated, suggesting that both forms of treatment induced a release of gonadotrophin from the anterior pituitary gland.

G. E. LAMMING

Endocrinology and ruminant nutrition. *Proc. Univ. Nottingham 7th Easter School Agric. Sci.*: 1960. 249-62.

Consideration was given to the possible areas where hormones could affect the growth rate of ruminants. Only in the self-inhibiting phase does it appear practical that hormones can be used to improve growth rate, and female sex-hormones administered to castrated males appear the most useful.

The information concerning use of these sex-hormones in sheep and cattle was reviewed and their possible modes of action discussed. It was concluded that the anterior pituitary gland is affected by sex-hormone treatment, enlarging the gland and increasing the total content of ribonucleic acid. Many of the effects of sex-hormone treatment are similar to those produced by administration of somatotrophin. A mild hyperthyroidism is probably produced but there is lack of evidence supporting that the adrenal cortex is involved in stimulating the extra nitrogen retention which is known to occur.

NORA McDERMOTT

Early potatoes—a survey of practices. (N.A.A.S. Technical Publication 165). London, H.M.S.O. 1960.

Techniques of production of early potatoes in Britain are surveyed in relation to location and other factors.

HORTICULTURE

J. P. HUDSON

General effects of potash on the water economy of plants. *Potash Symposium,* 1958: 95-108. (1960).

A short review followed by a detailed account of experiments on the effects of high soil salinity, induced by potassium and magnesium sulphates, on growth, yield and water use of glasshouse tomatoes.

Crops, chemicals and the weather. *Span,* **3**: 6-9. (1960).

A discussion of the possibilities of altering plant responses to environmental conditions by the use of chemical regulators, with special reference to work on phasic development of raspberry shoots.

A sensitive evapo-transpiration gauge. *Bull. Res. Council Israel,* **8D**: 263-72. (1960).

A detailed description of apparatus developed in the Department of Horticulture for measuring the rate of transpiration from plants and evaporation from the soil surface in blocks of plants grown at normal commercial spacings.

Relations between root and shoot growth in tomatoes. *Sci. Hort.* **14**: 49-54. (1960).

A review of the literature and general discussion on the significance of experimental results, leading to the suggestion that a method is needed for characterising the efficiency of root systems comparable with the methods of growth analysis applied to shoots.

Plants and their water supply. *New Scientist,* **8**: 1328-30. (1960).

Suggesting that measurement of actual transpiration rate under known meteorological and soil conditions should enable efficient irrigation schedules to be worked out for other soil and evaporating conditions (though not for other crops).

W. HEYDECKER

Problems of seedling establishment in the field. *Sci. Hort.* **14**: 63-74. (1960).

Review of recent literature on seed storage; control of seed- and soil-borne pathogens; seed rates for vegetable crops sown *in situ;* physical causes of failure of seeds to germinate and of seedlings to emerge from the soil, including air/water unbalance, limiting temperatures, crusting of soils; fertilizer placement and pre-emergence weed control.

Can we measure seedling vigour? *Proc. Int. Seed Test. Ass.* **25**: 498-512. (1960).

The vague concept of seedling vigour, as used by seed technologists, implies a quality not expressed by the results of the standard laboratory germination tests. The definition suggested here is ability of seed to germinate and produce a stand of seedlings under sub-optimal field conditions. Approaches to assessing this ability are reviewed and a test procedure is proposed in which a number of standardized adverse soil conditions are employed; these provide a broad base for measuring seedling vigour and may in addition indicate conditions under which certain stocks of seeds perform particularly well or poorly.

Wirksame Duengemittelanwendung. *Landw. Forsch.* **13**. (1960).

Review of Ignatieff, V. and Page, H. J. (eds.), *Efficient Use of Fertilizers,* 2nd ed., F.A.O. (1958).

D. W. T. CLAY and J. P. HUDSON

Effects of high levels of potassium and magnesium sulphates on tomatoes. *J. hort. Sci.* **35**: 85-97. (1960).

Describing experiments in which tomato plants were subjected to different salinity-regimes but where soil moisture tension was maintained at low levels. The results enabled a salinity of pC 2.9 to be defined as the critical level in moist soils where increased salinity would probably have significant effects on yield of tomatoes.

AGRICULTURAL ECONOMICS

K. A. INGERSENT and P. MANNING

New housing for dairy cows in the East Midlands. (1960). (University of Nottingham).

Upwards of 250 farms with new cowhouses or yards with milking parlours were visited and building costs per cow were found to be extremely variable. This was due, in the main to differences in building design and specification of materials rather than to different builders charging different prices for similar work. Nevertheless, the latter factor could not be entirely discounted and it was found that the contract procedure normally followed by farm-owners is scarcely conducive to effective competition between builders.

No association whatever was found between the level of milk production and the amount of money spent on new cowhousing accommodation and this in itself appears to be a strong argument for housing cows as cheaply as possible.

GWYN E. JONES and H. W. JOHNSON

Farming in the East Midlands: financial results 1959-60. (University of Nottingham. F.R. No. 142). (1960).

The Report, based on the accounts of about 250 farms, reviews changes in farm incomes, outputs and inputs since 1952-53 in actual and real terms, and discusses the main features of the financial results for 1959-60. Since 1952-53 net farm incomes in the East Midlands have declined. During the past two years the real net income of farmers has been only about 60 per cent of that six years earlier. Arable type farmers secured a relatively high income during 1959-60, but Livestock farms were adversely affected by the dry summer of 1959. A summary is also provided of the major inputs and outputs for farms in particular areas of the East Midlands.

The main tables show details of costs and returns for the average farm and the most profitable farms in six types of farming groups, each sub-divided into two size of farm groups.

Farm Management Notes. Nos. 23 and 24. Spring and Autumn, 1960.

This publication is issued twice yearly to over 1,200 farmers, advisory officers, British and Foreign administrative agencies, educational institutions and libraries. Short articles make available to the farming industry the facts, ideas and suggestions which arise from the research and advisory work conducted by members of the Department of Agricultural Economics.

LECTURES AND PAPERS—1960

P. M. BREMNER:

'Future developments in crop husbandry' to Leicestershire and Rutland Farm Institute.

R. L. BURT:

'Some aspects of growth of the potato in relation to temperature' to Society for Experimental Biology at Nottingham.

B. N. K. DAVIES:

'Study of soil micro-arthropods and their relation to land reclamation after open-cast ironstone mining' to Association of Applied Biologists at Sutton Bonington.

WINIFRED M. DULLFORCE:

'Factors affecting flowering in the chrysanthemum' to Northampton and District Chrysanthemum Society.

H. G. EVANS:

Course of four lectures to Farmers' Discussion Group at Oakham.

M. PATRICIA GRANT, R. B. HEAP and G. E. LAMMING:

'Influence of ovarian hormones on the development of ova in the ligated uterus of the rabbit' to Society for Endocrinology at London.

R. HALL:

'The Grasslands of Britain' to Oundle School Y.F.C.

E. G. HALLSWORTH:

'An analysis of the process of profile development' to Australian Society of Soil Science, Unviersity of Queensland.

'The teaching of Agriculture in the Universities of the United Kingdom' to Institute of Agricultural Science, University of New England, New South Wales.

'Agriculture at the University level' to Waite Institute, University of Adelaide.

D. W. R. HEADFORD:

'Relationships between sprout growth and the parent tuber in the potato' to Society for Experimental Biology at Nottingham.

'Sprout development of the potato' to First Triennial Conference of the European Association for Potato Research at Braunschweig-Volkenrode.

R. B. HEAP and G. E. LAMMING:

'Influence of ovarian hormones on the chemical composition of uterine secretions' to Society for Endocrinology at London.

W. HEYDECKER:

'Science, soils and stands of seedlings' to Surrey Horticultural Progress Club.

'Bees and pollination from the fruitgrower's point of view' to Nottinghamshire Beekeepers' Association Annual Meeting.

'Components of successful crop germination' to East Midlands Horticultural Conference.

J. P. HUDSON:

'Control of environment and its effects on growth of tomato plants' to Eastern Region Horticultural Conference at St. Albans and to Horticultural Conference at Riseholme.

'Effects of environment on *Rubus idaeus*' to Linnean Society at London.

'The plant environment in relation to ageing and development' at University of Reading.

'The water relations of tomato plants' to Society for Experimental Biology at Nottingham.

'Chemical control of plant responses to weather' to Horticultural Education Association at Bristol.

'Water relations of tomato plants' to East Midlands Horticultural Conference.

J. D. IVINS:

'Grass production and utilisation on arable farms' to Lindsey Crop Conference.

'Utilisation of grass for milk production' to N.A.A.S. Conference at Chester.

'Farming, food and science'—Inaugural Lecture, University of Nottingham.

'Grassland production' to Harrington Agricultural Discussion Society.

'Milk production from grassland' to Shropshire Milk Recorders' Conference.

'Looking ahead in crop production'—Devon County Agricultural Association Lecture, 1960.

'Digestibility data and grassland evaluation' to the 8th International Grassland Congress.

'The importance of crop variety' to Northamptonshire Farmers' Conference.

'Farming and food' to Nottinghamshire Branch of National Council of Women.

'The basis of animal production from grassland' to Somerset Farmers' Conference.

'Good grass crop husbandry' to Queniborough Discussion Society.

'8th International Grassland Congress—Grassland Management and Animal Production' to British Grassland Society.

'Rotations and crop yields' to N.A.A.S., Technical Conference at Cambridge.

G. E. JONES:

'Economic aspects of milk production' to Sleaford N.F.U.

R. BENNETT JONES:

'Economics in agriculture' to Sleaford N.F.U.

'Cereals on the dairy farm' at N.A.A.S. Conference, Oswestry.

'Work of the P.A.E.S.' to Farm Organisation Course at Leicestershire and Rutland Farm Institute.

'The scope of cost reduction within individual enterprises' to N.A.A.S. East Midland Region Farm Management and Work Study Course at Matlock.

R. BENNETT JONES (with T. W. D. Theophilus):

'Problems of cost reduction in agriculture' to Daventry District Agricultural Executive Committee, and to N.A.A.S. at Leicester, Oakham and Nottingham.

G. E. LAMMING:

'Hormones and meat production' to British Council Symposium on 'Recent Advances in Animal Reproduction' at Cambridge.

'The use of hormones in meat production' to Peterborough Farmers' Club.

'Endocrinology and ruminant nutrition' to University of Nottingham 7th Easter School in Agricultural Science at Sutton Bonington.

'The use of hormones for beef production in Great Britain' to International Conference in Buenos Aires.

'New techniques in beef production' to Farmers' Conference and Open Forum at Colchester.

'Agricultural education and research in U.S.A.' to School of Agriculture, Sutton Bonington.

'The effect of ovarian hormones on the chemical composition of uterine secretions' and 'The influence of ovarian hormones on resistance to experimental uterine infections' to American Dairy Science Meetings at Utah State Agricultural College.

B. G. LEWIS:

'Ecology of certain pathogenic micro-organisms on potato tuber surfaces' to Association of Applied Biologists at Sutton Bonington.

D. LEWIS:

'Physiology of animal digestion' to Association of Agriculture at Westham House Residential College.

'Metabolic pathways and the nutrition of pigs and poultry' to Association of Veterinary Teachers at Sutton Bonington.

'The fate of nitrogenous compounds in the rumen' to the University of Nottingham 7th Easter School in Agricultural Science at Sutton Bonington.

MARGARET E. MARSTON:

'Regeneration of plants from isolated leaves of *Streptocarpus*' to Society for Experimental Biology at Nottingham.

NORA McDERMOTT:

'Potato varieties and their management' to N.A.A.S. at Knutsford; Vaughan Horticultural Society at Leicester; N.A.A.S. and N.F.U. Southport; Osbournby Farmers' Discussion Group; N.A.A.S. Brigg; Potato Conference, Harper Adams Agricultural College.

F. L. MILTHORPE:

'Factors involved in the expansion of the leaf surface' to University of Leicester Biological Society.

'The growth of the potato' to Association of Applied Biologists at London.

'The nature and analysis of competition between plants of different species' to 15th Symposium of the Society for Experimental Biology at Southampton.

'Physiological aspects of potato growth' to A.R.C. Technical Committee on Potato Problems at London.

'The control of plant growth' to University of Edinburgh Botanical Group.

'Factors influencing yield in the potato' to National Association of Seed Potato Merchants at Sutton Bonington.

J. T. MORGAN:

'Recent developments in livestock production' to Leicestershire and Rutland Farm Institute.

'University entry requirements for degrees in Agriculture' to Leicestershire Headmasters' Association.

P. W. MURPHY:

'Acarina inhabiting the soil' to Institute of Acarology, University of Maryland.

'Some recent developments in soil zoology' to Department of Zoology, University of Colorado.

'Some recent developments in soil zoology' at Department of Entomology, University of Kansas.

'Research methods in soil zoology' to Department of Biological Sciences, Northwestern University, Illinois.

P. W. MURPHY (with D. K. McE. Kevan):

'The influence of soil animals on soil formation' to General Session of Seventh International Congress of Soil Science at Madison, Wisconsin.

T. H. NICOLSON:

'Disease of plants' to Leicester Literary and Philosophical Society.

'Vesicular-arbuscular mycorrhiza in the Gramineae' to International Symposium on Mycorrhiza at Weimar.

C. G. PAYNE:

'Problems of insulating and ventilating intensive poultry houses' to N.A.A.S., Horsham.

J. H. D. PRESCOTT:

'Calf rearing and heifer management' to Walton-le-Wolds Y.F.C.

'Methods of intensifying fat lamb production' to Wigston Magna and District Y.F.C.

E. M. SADLER:

'Sprout growth of the potato during storage and its significance in subsequent growth' to Society for Experimental Biology at Nottingham.

W. S. SENIOR:

'Economic effect of the introduction of grassland into an arable rotation' to North Lindsey District Agricultural Executive Committee at Brigg.

'Economics of the ley' to Wragby Agricultural Executive Committee.

W. R. SHORTHOSE:

'The use of hormones in beef production' to Grantham and District Y.F.C.

'Hormones for sheep production'—B.O.C.M. Field Day at Pickworth.

M. STEIN:

'Chemical additions to food' to Summer School in Food Science at Glasgow.

T. W. D. THEOPHILUS:

'Sources of capital for agriculture', 'Interpretation of farm accounts for management purposes', and 'Budgetting', at College of Technology and Arts, Rugby.

'Problems of small farms' and 'Problems of hill farming' to Buxton and Peak District Productivity Committee.

'Work study' to Underwood and Selston Farmers' Discussion Group.

'The scope of cost reduction in agriculture with particular reference to labour and machinery' to N.A.A.S. East Midland Region Farm Management and Work Study Course at Matlock.

'The use of accounts in farm management' to Chartered Accountants Students' Society of Lincoln and South Lincolnshire.

'Farm management' to Ashover Farmers' Club.

'Prospects in agriculture' to Rosliston Farmers' Discussion Society.

'Capital in agriculture' to Hinckley N.F.U.

T. K. WARLEY:

'Work study in horticulture' to the Yorkshire (West Riding) Institute of Agriculture and to Leicester Commercial Horticultural Discussion Society.

'Agriculture and European economic integration' to Kesteven Farm Institute.

'Management in horticulture' to N.A.A.S., Yorkshire and Lancashire Region at Fleetwood.

'Work study in agriculture' to North Riding N.F.U.

T. WEBSTER:

'Potatoes; planning for profit'—Farm Forum, Isle of Man.

'N.I.A.B. Cereal Trials' to Farnsfield and District Farmers Discussion Group.

W. J. WHITTINGTON and J. HILL:

'Growth studies on natural hybrids between *Lolium perenne* and *Festuca pratense*' to Association of Applied Biologists at Nottingham.

W. J. WHITTINGTON and W. E. PEAT:

'The inheritance and survival of the Xasta (Xa) mutant of *Drosophila melanogaster*' to Genetical Society at London.

M. WOODBINE:

'Food production by micro-organisms with special reference to fat' to a post-graduate course at Royal Technical College, Salford.

M. WOODBINE, A. SEAMAN and KATHLEEN N. SMITH:

'Some preliminary observations on the microbiology of broiler chickens' to the Society of Applied Bacteriology at London.

'Microbiological aspects of domestically refrigerated ice-cream' to Society of Applied Bacteriology at Bangor.

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Pedogenesis in the Southern Pennines. **M.Sc.**

CRAWFORD, D. V.

The effects of micro-organisms on the mobility of inorganic constituents of podzolic soils. **Ph.D.**

AGRICULTURE

COSTAIN, R. A.

Some effects of hormone administration and dietary protein level on pig productivity. **Ph.D.**

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Farming in the East Midlands: *Financial Results* 1959-60. (F.R. No. 142). (1960). 4s. 0d. JONES, GWYN E. and JOHNSON, H. W.

New housing for dairy cows in the East Midlands. A technical and economic survey. (1960). 10s. 0d. INGERSENT, K. A. and MANNING, P.

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The Measurement of Grassland Productivity. Proceedings of the Sixth Easter School in Agricultural Science, University of Nottingham 1959. Editor: J. D. Ivins. Publishers: Butterworths Scientific Publications, London, 1959. Price 35s. 0d.

Digestive Physiology and Nutrition of the Ruminant. Proceedings of the University of Nottingham Seventh Easter School in Agricultural Science 1960. Editor: D. Lewis. Publishers: Butterworths Scientific Publications, London, 1960. Price 50s. 0d.

CORRIGENDUM

REPORT OF THE SCHOOL OF AGRICULTURE 1959

Page 62 Foetal Development in Pigs—the authors should be 'F. R. Green and J. T. Morgan' instead of 'J. T. Morgan and F. R. Green'.

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